FISCAL YEAR 1985 DEPARTMENT OF ENERGY AUTHORIZATION

(Uranium Enrichment, Electric Energy Systems and Storage Programs)

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND PRODUCTION

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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1985 DEPARTMENT OF ENERGY AUTHORIZATION

WEDNESDAY, FEBRUARY 22, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
Washington, D.C.

The subcommittee met, pursuant to notice, at 1 p.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd (chairman of the subcommittee) presiding.

Present: Representatives Lloyd, Ottinger, and Walker.

Staff present: Dr. John V. Dugan, staff director; Louis Ventre, Jr., counsel; Dave Clement, minority counsel; and Bill Harvey, minority energy coordinator.

Mrs. Lloyd. The Subcommittee on Energy Research and Production will come to order.

Good afternoon, ladies and gentlemen. The Department of Energy, the administration and the Congress are confronting a difficult situation with respect to the uranium enrichment program. Much of the problem is caused by factors beyond our control, including artificially low prices of international competitors as well as the availability of services from a significant secondary market, and the situation has been somewhat aggravated by the Secretary of Energy's contention that he will seek no net appropriation for the program in any fiscal year independent of the revenues collected. All of this is taking place as the Department awaits responses to its new uranium enrichment contract.

As a result, the temptation is indeed great in this budget climate, with deficit fever rampant, to make some easy choices based on very nearsighted assumptions. It is clear to me that this country cannot walk away from its recent capital investment in the enrichment enterprise. Rather, we must forge an overall strategy which begins with issuance of the new contract to complete some fraction of the gas centrifuge enrichment plant, and plan to handle additional capacity requirements with follow-on AIS plants. The goal of the enterprise should be clear: That is, to achieve the lowest cost services while attempting to arrive at optimum utilization of developing industrial infrastructure while conducting advanced technology trade-offs.

As the advanced technologies near demonstration, however, we must realize the Department faces some hard decisions in the implementation of an interim strategy. Such a strategy ultimately must involve phased shutdowns of gaseous diffusion plants and a recognition of secondary market possibilities as a contingency for additional supply requirements. The forging of these interim and long-term strategies in terms of budget requests and related actions will require a solid and patient commitment on the part of both the executive and legislative branches.

I think that we should remind ourselves that the uranium enrichment enterprise unfortunately cannot be conducted with the desirable flexibility of a private business. Also, it may be useful in this regard to think of the administration as the chief executive and operating officers of the uranium enrichment enterprise, with the Congress serving as the board of directors.

As we know, there has been much written recently about the great tendency for CEO's to think only of near-term profits to the neglect of long-term business planning. The Congress must look beyond today's marketplace for enrichment services, and demonstrate the resolve to see this program through. Perhaps our commitment will encourage the operating officers to look over the technological horizon to the day when the United States can again compete because it offers the lowest cost services.

This afternoon we are going to hear from Dr. Shelby Brewer and Mr. John Longenecker on this very important program in the fiscal year 1985 DOE request. We are happy to have you gentlemen here.

Mr. Walker, I think you have an opening statement for us.

Mr. WALKER. Thank you, Madam Chairman. I join with you in welcoming Dr. Brewer and Mr. Longenecker to the committee today, and thank you for continuing to conduct the hearings which try to put the 1985 budget request into some perspective. As we deal with the enriched uranium issue, we are of course dealing with one of the more important aspects of that energy budget request as it affects this subcommittee.

We will want to look at some of the issues, for instance, the issues that we raised last year. The committee asked DOE in the report last year to conduct a comprehensive review of the pricing formula for enrichment services, including an assessment of the propriety of including computed interest in that pricing formula. We will be interested in a followup to what has been done in that regard.

It also seems to me that one of the things we may want to look at as a subcommittee and in conjunction with the Department of Energy is what kind of a good market study can be put together to give us some idea as to what the enriched uranium market is going to be in the future. It seems to me that we need to have a basis on which to make our judgments, and that such a market study might well provide us with the baseline data that we need in order to decide some of the directions and budgetary commitments we have to make for the future.

So, Madam Chairman, I thank you for the hearings today and I thank the witnesses for appearing before us.

Mrs. LLOYD. Thank you very much, Mr. Walker, for your help and your interest in this committee.

Mr. Winn also has an opening statement. Without objection, it will be made a part of the record.

[The opening statement of Mr. Winn follows:]

STATEMENT BY THE HONORABLE LARRY WINN, JR.

ENERGY RESEARCH AND PRODUCTION SUBCOMMITTEE

FY 1985 DOE AUTHORIZATION FOR URANIUM ENRICHMENT R&D

FEBRUARY 22, 1984

THANK YOU, MADAM CHAIRMAN. I, TOO, WISH TO EXTEND A WELCOME TO DR. BREWER AS WE CONSIDER THE URANIUM ENRICHMENT PROGRAM TODAY. WE ALL AGREE THAT IT IS A PROGRAM WITH A LOT OF CHALLENGES.

WE CAN EASILY POINT TO A NUMBER OF REASONS FOR ITS PRESENT CONDITION. IN ADDITION TO THOSE MENTIONED IN DR. BREWER'S TESTIMONY, WE COULD ADD THAT NATIONAL ENERGY FORECASTS MADE IN THE 60'S AND 70'S WERE TOO HIGH. THE LOWER PRICE OF CRUDE OIL WAS NOT PREDICTED. THE DROP IN INTERNATIONAL POWER REQUIREMENTS ALSO CONTRIBUTED. INABILITY TO FORECAST ACCURATELY HAS PLAGUED MANY INDUSTRIES, BUT IN THIS PROGRAM WE DO NOT HAVE THE FREEDOM TO CHANGE RAPIDLY AND AT MINIMAL COST WHEN THESE FAULTY FORECASTS ARE PERCEIVED. THE URANIUM ENRICHMENT PROCESS IS CAPITAL INTENSIVE TO THE EXTENT OF DOE'S INVOLVEMENT.

It is encouraging to hear that a new, more flexible contract is being offered to present and prospective customers. I hope their response will be positive and vigorous. Uranium enrichment is a competitive business and you must meet market conditions to survive. Through all this discourse on the market and its demands, I have heard no word on DOE's goals. How much of this market do you want? I know you once enjoyed a monopoly but I suspect those days are gone forever. Do you want to meet all the domestic requirements? Seventy-five percent? Half the foreign needs? Twenty-five percent?

Having established some percentage of the demand as a goal, then it seems reasonable to arrive at the means to achieve that goal. You may find that insurmountable institutional barriers prevent reaching that goal. Then you fall back to a lesser goal, and so on. I am told that major corporations make no plans for constructing facilities until they have a sales forecast in hand. I am advised that sales forecasts are made frequently. The trend, as well as the amount, is instructive. This sales forecasting business may not be DOE's strength but there are resources that you can call on for assistance.

Given the conditions which we agree do exist, I have trouble accepting your projection that DOE sales in 1991 will exceed volume in 1985. By your admission the forecast for the year 2000 is much lower in January 1984 than it was 14 months earlier. So, I see some optimism in your data which is rather difficult to justify.

Madam Chairman, I can only repeat my understanding and concern over the problems which the uranium enrichment program faces. The solutions lie beyond innovation. Hopefully new technologies and business orientation will help.

Thank you, Madam Chairman.

Mrs. **Lloyd**. Shelby, we're awfully happy to have you back with us again, as well as you, John. We look forward to your testimony. You may proceed.

STATEMENT OF SHELBY T. BREWER, ASSISTANT SECRETARY FOR NUCLEAR ENERGY, U.S. DEPARTMENT OF ENERGY, ACCOMPANIED BY JOHN R. LONGENECKER, DEPUTY ASSISTANT SECRETARY FOR URANIUM ENRICHMENT

Mr. **Brewer**. Thank you, Madam Chairman.

As you know, this past year we have indeed confronted a market crisis of very severe dimension in the enrichment enterprise. It was a business crisis, a market fall-off, and it threatened our ability to remain a long-term, reliable, indigenous supplier of enrichment services.

The problem, as you have pointed out, is traceable to factors both external and internal to the program. About 1 year ago I brought what were then relatively mild symptoms of the problem to the Secretary's attention, and proposed a business strategy for turning the situation around. That basic strategy has now been mobilized and, based on early returns, I am more optimistic than I have been in the past year that more damage can and will be averted.

It is a very complex problem. It's fundamentally a market crisis, a business problem, and I presented a dissertation to Mr. Ottinger's committee on October 21 on the market aspects of the situation and its' underlying causes. At that time, the details of our response to the crisis had not been finalized, and I was not in a position to discuss the remedy.

I am prepared now to discuss both the problem and the outline of our response to the problem. Because the matter is complex, with many roots and tentacles, and because it is gravely important, Madam Chairman, I would like, with your permission, to spend some moments in recapping the history of the evolution of the enrichment market, how the market problem that we encountered this past year came upon us, and the rationale for our response to the market problem.

Mrs. **Lloyd**. Without objection, and your entire statement will be made a part of the record, so you may proceed as you wish.

Mr. **Brewer**. Thank you.

As you know, in the early 1960's, with the Private Ownership Act, nuclear materials were allowed for civilian use. The private ownership applied to utilities who had or who were ordering nuclear powerplants, and in the 1960's the toll enrichment services were offered by the U.S. Atomic Energy Commission. The contract form that was developed at that time was a so-called requirements contract with great flexibility to the customer.

In the early 1970's there was a shift to long-term fixed-commitment type contracts. This was at a time when the Atomic Energy Commission was anticipating a very large growth rate in nuclear power—some 1,200 gigawatts were projected by the turn of the century—and more capacity in enrichment was thought to be needed. In 1974 the books were closed because the gaseous diffusion plants were forward-saturated with commitments to produce separative work units. The interpretation of the law at that time was that no new contract can be signed without an additional increment in enrichment capacity.

Between 1974 and 1978 when the books were opened again, foreign competition developed—EURODIF and URENCO—and between 1973 when we had a total world monopoly, 100 percent of the world market, and 1980 our share of the total market had declined to about 35 percent or about a third of the world market, largely because our books were closed and we were accepting no new contracts. This encouraged the competition to enter the market and gain about a 65-percent share. The other factor that impinged on our market was our image between 1977 and 1980 as an unreliable supplier of nuclear hardware, of nuclear fuel and separative work services.

In the 1981-82 timeframe we were intent on restoring our market position abroad, and in fact made some headway. We gained a few percentage points in the world sweepstakes. There was a contract signed with the Egyptians and we continued to service our Japanese customers. Up to that point there was no erosion of our domestic market. We still had 100 percent of the U.S. domestic customers.

Then in 1982 we began to see some hairline cracks in our domestic market. For the first time we began to see some U.S. utilities turn to the foreign secondary market, and this revenue loss was occurring at a time when Federal budget constraints were extremely tight and we were engaged in major new construction and development activities. The underlying causes for this domestic erosion were largely three factors: a large and growing world secondary market, fed by overproduction here and abroad, and this secondary market could underprice U.S. production at DOE facilities.

A second factor, perhaps the dominant factor, was a major shift in foreign currency exchange rates. One American dollar could purchase twice as much product in 1983 from Europe than it could in 1980. Over and above these external factors, the U.S. enrichment enterprise was operating as if it were still a monopoly. It had burdened its customers with burgeoning expansion and development costs and was locked into rigid pricing and marketing prices. In other words, the U.S. enrichment enterprise was not operating like a business, for many factors external to the program.

So in 1983 we had a considerable loss of U.S. domestic market to the foreign secondary market. This was because U.S. customers represented the only outlet for excess foreign-origin SWU's. We are the only producer who offers a true requirements-type contract, and these excess foreign SWU's could underprice, as I said, any SWU newly produced because their holders could economically discount the price rather than hold the SWU's indefinitely and gather carrying charges, against the possibility that they would someday be needed.

The other factor that encouraged purchases by U.S. customers in this market was the fact that they could be bought in devalued currencies. As I pointed out, the franc went from 4 francs to the dollar to 8 francs to the dollar. Also in 1983, in addition to losses to the foreign secondary market—that's the market fed by excess SWU's which are not needed—some U.S. customers showed inclinations toward canceling our contracts in favor of other prime sources or producers such as EURODIF and URENCO because, as I said, they were priced in devalued currencies.

To summarize, the world market at this time is a buyer's market. There is a glut in both capacity and in production. The capacity glut is reflected in the fact that the world has something like 42 million SWU's per year in capacity when at this time it needs about 20 million SWU's. It's about a factor of two in capacity, overcapacity, and of course the existence of SWU's which have been produced or committed are reflected in the secondary market. There is an excess of SWU's as well as capacity to produce SWU's. Finally, the strength of the U.S. dollar is the third major factor, and the fourth is an attitudinal problem. We are no longer a monopoly, although we have tended to act like one in the seventies and early eighties.

Now our response to this market crisis has two fundamental elements: first, to stabilize our share of the market, and then to revise the production strategy accordingly. Our overall objective is to stabilize our trajectory through this transient market phenomena and to remain solvent during these years, and to emerge in the late 1980's or early nineties with a commanding real price advantage through advanced technology.

Stabilizing our share of the market will be accomplished by the new contract offering. There are three major features of the new contract. First of all, it is a requirements-type contract, not a fixed commitment type contract—take or pay—and it's based on the customer's actual needs. Therefore, we will not continue to force-feed unneeded SWU's into the secondary market.

A second major feature of the contract is that it allows for an offset of up to 30 percent of a customer's requirements from sources other than the Department of Energy. This feature is designed to encourage drying up, burning out the secondary market, and transferring those benefits to the consumer, the utility, and the ultimate electricity consumer, by mixing lower priced SWU's with the SWU's newly produced.

A third major feature, Madam Chairman, is the price ceiling of $135 per SWU in fiscal year 1985 and adjusted thereafter by known national or regional indices, or inflators, rather than a pricing formulation based on estimates of future enterprise cost. One of the principal items that the customers have desired is predictability in our cost and our price formulation. They will now have it, because they will be able to estimate the price as easily and as well as we can by reading national inflators and the Wall Street Journal, or whatever.

The contract is designed to maximize customers' flexibility—the requirements feature, the offset feature, the variable tails assay feature—while providing the U.S. Department of Energy with a firm basis for production planning, and the new contract, I should point out, reflects a fundamental shift in philosophy and business practice. We will design and plan the production strategy—that is, how we operate the diffusion plants, the advanced research and development program, and the deployment of advanced enrichment technology—by the amount that the market will bear.

Mrs. Lloyd. Shelby, excuse me. You offer the utility a service contract and you announce this lower price ceiling, and you just indicated that this year's operating strategy will depend on the extent of conversions to a new contract. Is that correct?

Mr. **Brewer**. Yes. The conversion period closes October 1. If we get 50 percent of our customers to convert, our ability to finance cost above and beyond production cost will depend on the number of conversions we get.

Mrs. **Lloyd**. It assumes that you are completely successful in retaining your customers. How do you recover all your costs at this lower price?

Mr. **Brewer**. Can I have the slide, please?

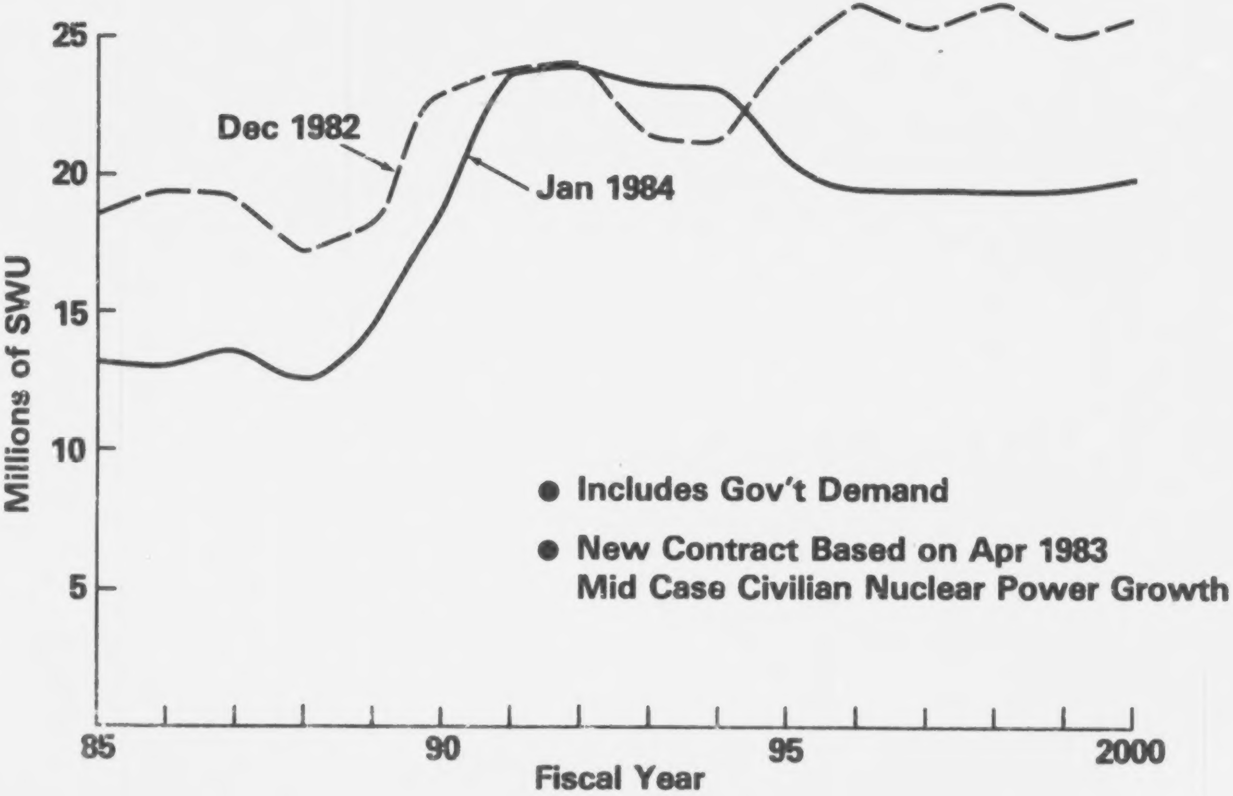
We have and will be making a more cost-effective production strategy. There are several ways of doing this. We can trim the TVA demand charges. We can operate the diffusion plants more effectively. We can slow the construction at the gas centrifuge project at Portsmouth, and other economies.

Mrs. **Lloyd**. Well, you feel that you have enough flexibility in this new operating strategy to give you the confidence that you can live with this $135 price ceiling?

Mr. **Brewer**. Yes, I do, Madam Chairman.

Figure 1

Projected DOE SWU Sales



- ● Includes Gov't Demand
- ● New Contract Based on Apr 1983 Mid Case Civilian Nuclear Power Growth

The chart that you see over there (figure 1) gives the range of possibilities. Unfortunately, it's not labeled very well but with the lower curve, the bottom of the chart, the gray area reflects only 50 percent of our customers converting to the new contract and that they convert at a minimum take fraction—that is, 70 percent. Even in that Draconian scenario, we are able to produce separative work units and do a considerable amount of research and development and deployment of advanced technologies over and above the production cost at the $135 per SWU.

Mrs. **Lloyd**. Thank you.

Mr. **Brewer** This concludes my prepared remarks, Madam Chairman. Again, I must stress that our response to the market is now taking place with the offering of a new contract. We are establishing a firm floor to our commitments to produce SWU's. When that process is complete, we will add in the filigree and the detail of the production plan, but our enterprise objectives are twofold: one, to get through this market transient in the next several years and, two, to emerge at the other side of this transient in a commanding technological and economic position, and I believe that we can and must accomplish those objectives.

[The prepared statement of Mr. Brewer follows:]

STATEMENT OF SHELBY T. BREWER
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
DEPARTMENT OF ENERGY
BEFORE THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
U.S. HOUSE OF REPRESENTATIVES

February 22, 1984

Madam Chairman and Members of the Subcommittee, I am pleased to be here today to discuss the Department of Energy (DOE) FY 1985 budget for the Uranium Enrichment program.

Accompanying me today is John R. Longenecker, the Deputy Assistant Secretary for Uranium Enrichment.

The funding request is approximately $1.7 billion in Budget Authority which is fully offset by $1.7 billion in projected revenue. The requested funds are distributed among the major program elements as indicated in the following table.

URANIUM ENRICHMENT

Major Program Element	FY 1984	FY 1985
	($ in Millions)	
URANIUM ENRICHMENT ACTIVITIES		
Power	$1,060.0	$ 883.3
Enrichment Research & Development	189.3	150.0
Gas Centrifuge Enrichment Plant	580.5	350.0
All Other	362.2	292.0
Total Uranium Enrichment Activities	2,192.0	1,675.3
URANIUM RESOURCE ASSESSMENT	1.8	0
Total Appropriation	2,193.8	1,675.3
URANIUM ENRICHMENT REVENUES	-2,105.0	-1,675.3
Net Appropriation	$ 88.8	$ 0

NOTE: The FY 1984 numbers reflect comparabilities.

The FY 1985 request represents a 24 percent reduction from the FY 1984 appropriation. I will now describe the reasons underlying this rather dramatic change.

Decreased demand, DOE's business practices, and the drastic change in currency exchange rates have frustrated our attempts to be a competitive supplier. The problems we identified a year ago--a worldwide excess of enriched uranium, increasing competition from foreign enrichment suppliers, and the emergence of a secondary market for uranium--are still with us today. As a result, the U.S. share of the global enrichment market has dropped significantly from the monopoly it held 10 years ago. Customers, understandably, have turned to suppliers that can offer lower prices and more flexible contract terms for their enrichment services.

The problem is portrayed graphically in Figures 1 and 2. Figure 1 compares DOE sales projections as of December 1982 with the current projection, including the potential impact of the new enrichment contract. The decrease in demand from the December 1982 estimate through the early 1990's reflects a drop in the growth of nuclear powerplant construction, further penetration of the secondary market, and the work off of excess inventories. Figure 2 shows the large difference that exists through 1990 between the costs associated with the December 1982 operating plan and expected revenues. The December 1982 plan anticipated construction of the full eight-building Gas Centrifuge Enrichment Plant (GCEP), continuation of an aggressive research and development program, and comparatively high production levels for the three gaseous diffusion plants (GDP).

This complex situation has caused us to rethink the entire strategy of the U.S. enrichment enterprise. It is clear that we must revise our program if we are to stay in business and compete effectively.

Over the past year we have analyzed this situation carefully, considered alternative options, and developed a strategy that we believe will significantly improve our market position. Our most pressing needs are to stabilize our market share, to provide for an orderly reduction of excess world inventories of enriched uranium, and to control our costs to match projected revenues.

Overall Objectives

The overall objectives of DOE's revised enrichment strategy are as follows:

1. To be responsive to the needs of our customers;
2. To be a reliable long-term supplier at predictable prices;
3. To offer enrichment services at the lowest reasonable price based on sound business practices; and
4. To operate the enrichment complex without Federal subsidy.

In meeting these objectives the Department will focus on three key elements: (1) issuance of a new contract responsive to customers' needs; (2) initiation of actions to plan and conduct the activities in each business element of the enterprise in a cost efficient manner; and (3) initiation of actions to encourage private sector interest and participation.

Utility Services Contract

Our first step is to offer a new contract with terms sufficiently attractive to retain our present customers and to interest potential new customers. After consultation with many knowledgable sources, this step was taken on January 18th, with the issuance of a new Utility Services enrichment contract.

The key features of the new contract are:

- A reduced price for separative work both in the near and long-term with a long-term price ceiling
- Ability to offset a portion of requirements by purchase from the secondary market
- Ability to purchase a portion of requirements from foreign sources
- Shorter lead times (180 days) to firm up delivery quantities
- Flexibility to select variable tails assay option
- Flexibility to terminate contracts with no termination charges provided 10 years advance notice is given to DOE

Overall, the new contract offers significant advantages to our existing customers and to prospective new customers. Fixed Commitment customers have the opportunity to convert to a contract with a substantially shorter fixed commitment period, to gain partial relief from their existing contractual future year delivery commitments, and to work off their existing excess inventories. Requirements customers would benefit from the lower price and from the ability to purchase a portion of their needs from the U.S. and foreign secondary markets at even lower prices. In addition, Requirements customers could use the variable tails assay option that they currently cannot do.

On February 6, 1984, I signed the first Utility Services contract with Duke Power with a value of over $2 billion in future sales. Duke elected to purchase 100 percent of its requirements from DOE. This action, we believe indicates that the new contract has a good likelihood of obtaining a high rate of conversion. We are redoubling our intensive sales and marketing efforts with our foreign and domestic customers to gain early and substantial conversions.

Control of Program Costs and Customer Prices

The key to remaining competitive in the enrichment marketplace is to offer a contract with favorable price and flexible terms. Continuation of the previous strategy with large outlays for GDP operations, Gas Centrifuge Enrichment Plant (GCEP) construction, and the development of advanced technologies would make it difficult to offer competitive prices to our customers in the near term. The earlier strategy was creating a cash flow drain of severe proportions, raising serious concerns about our prediction of price stability or price reductions in the long term. Accordingly, we are undertaking a vigorous cost reduction program with two major components.

The first involves the operation of existing production capacity. DOE is making an earnest attempt to obtain relief from the Tennessee Valley Authority (TVA) demand charges, to reduce outlays for GDP operations, and to operate the existing complex in the most cost efficient manner possible. After the extent of conversions to the Utility Services contract is determined, DOE will assess how many GDPs to operate, the operational mode of GDPs, future power purchases, reduction of program overhead, etc. These decisions cannot and should not be made until hard market data are in hand, but our strategy includes a firm commitment that we will pursue effective cost control both in the near and long term. This commitment is illustrated by the offer of a cost ceiling in the new contract.

The second cost control element relates to future investment decisions, including the level of research and development and the construction of new capacity. These decisions also will be market driven. In the near term, our strategy includes a continued commitment to developing and deploying new technologies for uranium enrichment. The funding level and pace of these programs, however, will be based on a more businesslike approach of adjusting outlays in proportion to revenues. As demand for separative work increases, the amount of money available for research and development on advanced technologies will also increase. Conversely, decreases in the DOE sales base would mean decreased activity and longer lead times for developing advanced technology options.

In the near term, we plan to continue research and development of both the advanced gas centrifuge (Set V) and the Atomic Vapor Laser Isotope Separation (AVLIS) processes. A detailed evaluation of both processes is under way that will assess the technical feasibility and economic potential of both options. A schematic summary of the key steps in this process is shown in Figure 3. DOE's objective is to determine at the earliest possible date which of the two should be pursued through the demonstration and deployment stage. We believe that we will be in a position to make this decision in mid-FY 1985. Recently, we have begun the process of establishing detailed evaluation criteria with the help of the advanced gas centrifuge and AVLIS program participants. We also plan to place an independent third party under contract in the very near term to assist us in the evaluation. The technology option that is not selected may be continued at a reduced pace to assure that a fallback alternative exists. Our FY 1985 budget reflects this approach, with research and development expenditures set at about nine percent of expected revenues. In future years, total research and development expenditures will be set based on development needs and available revenues.

With regard to new capacity, the Department intends to proceed in FY 1985 with construction of Process Buildings 1 and 2 in GCEP and procurement of

Set III centrifuges. Construction beyond Process Buildings 1 and 2 will be determined by response to the new contract and results of the technology selection. We are now rescoping the GCEP project to minimize overall project costs particularly the outlays for procurement of Set III machines. This course of action allows the pace for completion of GCEP to be driven by the marketplace. It also provides the potential for enhancing the economic viability of GCEP by introducing the more efficient Set V machine into a greater portion of the first two buildings, provided its development is successful.

Private Sector Participation

Another consideration in DOE's strategy is to finance future capacity additions like GCEP by private sector participation to the degree possible. This will assure that those who benefit from the new technology will also bear its cost. It is our objective to present specific recommendations to the Congress in concert with the FY 1986 budget.

Summary

In summary, the new uranium enrichment strategy reflects a major departure from past practices. It is market-driven and relies heavily on proven business practices. We believe it will have significant benefits to our customers and their rate payers, and to the country as a whole. The Department is seeking to improve its competitive position in the uranium enrichment business; to provide domestic utilities with a reliable indigenous supply of fuel; to assure that our defense requirements are met; and to see that the needs of foreign nations are met in furtherance of nonproliferation objectives. We will commit to meeting the long-term needs of our customers commensurate with their commitment to continue to rely on DOE for enrichment services.

We are looking forward to working with the industry and the Congress to assure that the uranium enrichment enterprise is responsive to these objectives.

Madam Chairman, this completes my formal statement. If there are any questions, I would be pleased to answer them at this time.

Mrs. LLOYD. Thank you very much for your testimony. Shelby, it just occurred to me when you were presenting your testimony, perhaps if we had not shut the doors in 1973 or 1974 but had expanded our capacity, we might not have created the marketing conditions we found ourselves in.

Mr. BREWER. Madam Chairman, with 20-20 hindsight I agree completely. There were several decisions, with 20-20 hindsight back in the 1970's, I believe, that would not have been made had the program managers at that time understood what was coming down the pike in terms of market. There was not an understanding of the market, and many of the contracts that were held or let in those days turned out to be nothing but a handful of paper.

Mrs. LLOYD. Well, maybe we can look ahead. I certainly hope that we can look ahead and expand our market by continuing to build and improve our capacity and our marketing procedures as well.

Am I correct that DOE is operating at about one-third of its capacity at our gaseous diffusion plants?

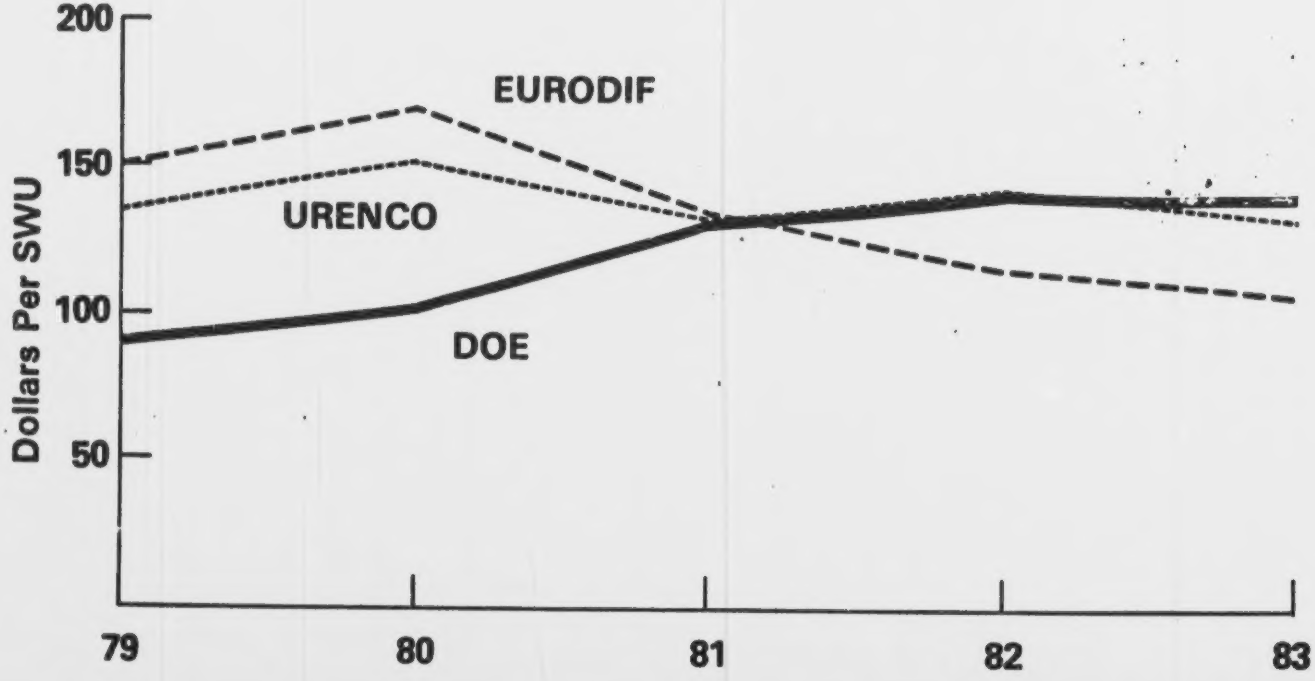
Mr. BREWER. Yes, ma'am. We are operating at about 40 percent of capacity at the three diffusion plants at Portsmouth, Oak Ridge, and Paducah.

Mrs. LLOYD. What are the prices for our competitors for SWU's, secondary market or EURODIF?

Mr. BREWER. There are two competitors, one the secondary market itself. That market can price a SWU and has priced SWU's as low as $90 at the time when we were pricing at $140 or $148 or thereabouts. The other producers, EURODIF and URENCO, are producing at about $110 per SWU.

FIGURE 2

SWU Price History By Supplier



You will note on this chart, Madam Chairman, that until 1981 we had a commanding price advantage over the other two producers. In 1981, due largely, if not entirely to the strength of the U.S. dollar, we fell into a disadvantage because, as I said, the franc and the deutsche mark were devalued relative to the dollar.

Mrs. **Lloyd**. So you attribute this entirely to the devaluation?

Mr. **Brewer**. Two factors: The devaluation in 1981 of the deutsche mark and the franc, and the existence of this large world inventory which was not——

Mrs. **Lloyd**. The secondary market?

Mr. **Brewer**. The secondary market.

Mrs. **Lloyd**. OK. Do you have a calculation of the degree of the secondary market at this present time?

Mr. **Brewer**. Yes. We have estimates of the extent of the secondary market, and it generally is in the range of about 3 years of world production. In other words, the producers, including ourselves, could quit producing for 3 years and the secondary market could carry the needs for those 3 years.

Mrs. **Lloyd**. It is my understanding the Portsmouth plant is the only one of the three diffusion plants that can be segmented and partially closed down. Is that correct?

Mr. **Longenecker**. Madam Chairman, the Portsmouth plant, as well as the Paducah plant, do have separate cascades that can be operated as separate units. The Portsmouth plant is divided into the portion that produces the low-assay material for civilian sales, and as the top end which produce high-assay material for naval propulsion and for weapons purposes. The Portsmouth plant is unique in that regard.

The Paducah plant is designed as essentially two unique units that can be separately operated, although it produces only low-enriched material.

Mrs. **Lloyd**. Well, what do you think the ramifications are for closing down one-half of Portsmouth to save money and allow the other plants to operate at a higher level? Would you provide an assessment of this option, if it is a little bit too detailed, for the record?

Mr. **Longenecker**. Madam Chairman, we have looked at the relative pros and cons of each of the GDP plants. At this point in time it's not obvious to us that we could shut down a plant immediately and in the long term have adequate capacity to meet our total demand.

What we see is, at the current time, are very low projections of sales due primarily to the existence of the secondary market. Once that material is gone and there are no inventories, and we project that that will be in the early 1990's, our sales could increase to a level such that the capacity of two GDP's could not meet the total demand of our customers that we are contractually committed to meet.

We, therefore, have said in fiscal year 1985 that we will operate all three gaseous diffusion plants, but at the minimum power level and with the minimum overhead costs possible, such that we retain the flexibility that when we get the response to the new utilities services contract, we can make a decision on the future operational mode of the three GDP's. If you recall Dr. Brewer's statement, the response to the utility services contract will give us 10 years' firm requirements from our customers to use as a planning base.

Mrs. LLOYD. If you finish half of Portsmouth and temporarily buy on the secondary market, why couldn't you leave all the plants in operation?

Mr. LONGENECKER. I don't believe I understood the question, Madam Chairman.

Mrs. LLOYD. Why couldn't you shut one of the plants down?

Mr. LONGENECKER. Well, Portsmouth, first of all, has the lowest production cost of any of the plants, primarily due to the cost of energy there. The power that we buy from OVEC is absolutely the cheapest of the three plants, so our production cost there is substantially lower than what we would need to purchase on the secondary market.

Mrs. LLOYD. What I was referring to is finishing half of GCEP at Portsmouth.

Mr. LONGENECKER. Oh, I see. I apologize. I was thinking you were speaking of the Portsmouth gaseous diffusion plant.

Mrs. LLOYD. No.

Mr. LONGENECKER. The pace for finishing GCEP, as proposed in the fiscal year 1985 budget, is such that it does not produce an appreciable amount of enriched uranium in the early 1990's, so that the GCEP capacity in the timeframe in which there is secondary market material to buy is not really a factor. GCEP, as you recall, one of the highlights in our program this last year was on November 27, 1983, installing the very first centrifuge in building No. 1 of GCEP. We will continue to fill that building. We have about 120 machines or one cascade there now, and we will not have any production from the GCEP facility until the late 1985 timeframe. We won't get any appreciable amount over 1 million SWU's until nearly 1990.

Mrs. LLOYD. How many buildings is DOE proposing for GCEP and how much construction have you done?

Mr. BREWER. It was designed for eight buildings. We have now committed to two buildings. These two buildings are essentially complete. We have deferred a decision on buildings three through eight until the market, as I said, settles out and we have a firm basis for designing the production plan.

Mrs. LLOYD. What is the estimated cost of the enrichment services from the proposed GCEP?

Mr. LONGENECKER. Madam Chairman, it's dependent, of course, on the number of buildings which we build and the technology, whether it is set III, IV, or V.

Mrs. LLOYD. For the two buildings, is what I am referring to.

Mr. LONGENECKER. Yes, ma'am. With a two-building GCEP with the set V machines installed, we currently estimate that in fiscal year 1985 dollars the full cost of those SWU's from that plant would be $100 per SWU. On an incremental cost or a cost-to-go, assuming the two buildings at GCEP, the costs through fiscal year 1984 are sunk, it's $57 per SWU.

Mrs. LLOYD. That's the two-building GCEP using set V machines?

Mr. LONGENECKER. Yes, ma'am.

Mrs. LLOYD. OK. What about for four buildings using set V machines?

Mr. LONGENECKER. Those numbers that I gave you decrease: for a full cost recovery in fiscal year 1985 dollars, $62 per SWU, and for an incremental cost, $40 per SWU.

Mrs. LLOYD. Well, given that it's very important that we maintain our manufacturing experience by purchasing our set III machines, would you be specific for us and identify the components of the set V machines that will be manufactured, using a similar technique as you would for the set III machines?

Mr. LONGENECKER. Madam Chairman, the set V machines and the set III machines are similar in their size and in their design. It is primarily in the materials of construction that are the differences between them, so the experience gained on the set III machines, the static and dynamic tests and the operational experience will by and large be applicable to the set V machines.

Mrs. LLOYD. Thank you very much. Let's turn to our AVLIS technologies. Is it possible that there will be insufficient revenues in fiscal year 1985 to carry both our centrifuge program and our AVLIS technologies?

Mr. LONGENECKER. No, ma'am. We have proposed in our fiscal year 1985 budget $150 million for both technologies. We have proposed an apportionment of those funds, $78 million being spent on AVLIS and $72 million being devoted to the advanced gas centrifuge, so both of those are reasonably healthy program levels right now.

Mrs. LLOYD. Will you be terminating one of the advanced enrichment technologies in 1985?

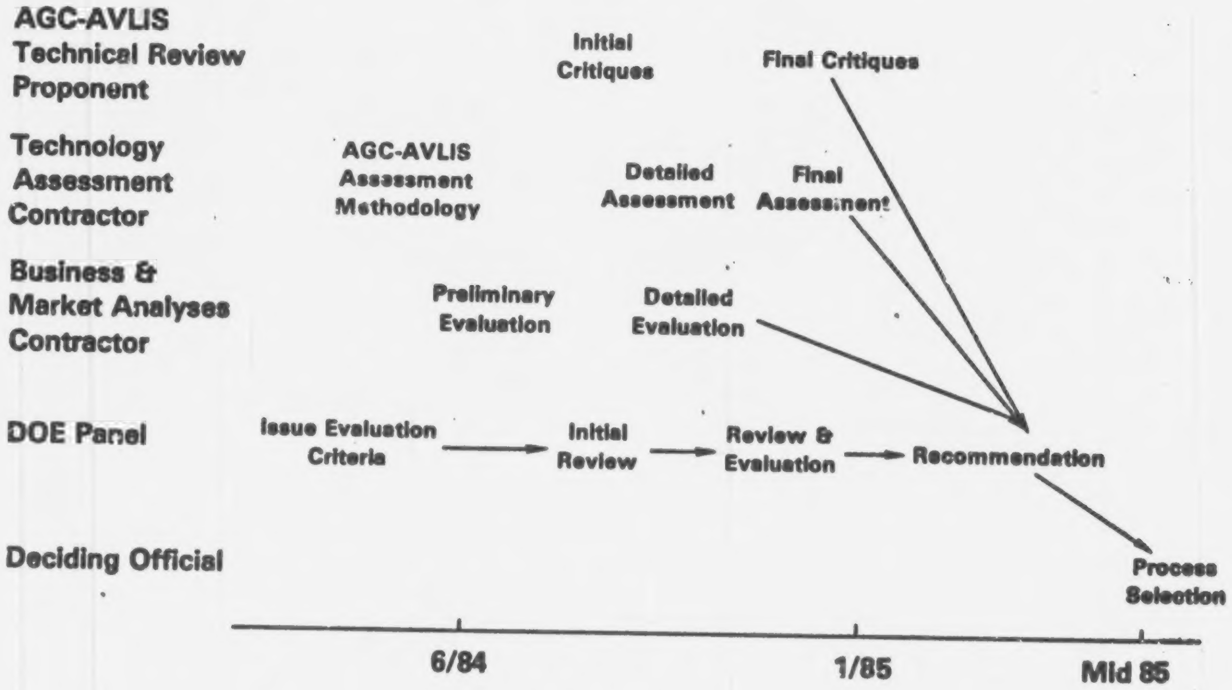
Mr. LONGENECKER. What we are proposing is a selection between the two technologies in mid-fiscal year 1985. We have begun and will continue through fiscal year 1984 and into fiscal year 1985 an assessment of the two technologies and their potential for, one, being technologically feasible and meeting their production goals and, two, being economically feasible and meeting the low separative work costs that have been projected for both to date.

The primary reasons for doing that are twofold: First, the primary reason that we do research and development in the first place is to offer lower prices to our customers in the future. Clearly they are signing long-term contracts with us, 30-year contracts. They are interested in not only today's price but what our price will be 5, 10, 20 years hence. It is important to our customers and to our long-term competitive position that we have advanced technology. We are firmly committed to that.

The dilemma that we find ourselves in is that the technology program that we had laid out in fiscal year 1984 is one that assumed that we would need new capacity in the early 1990's and, therefore, should carry both technologies through full scale demonstration.

Figure 3

Key Steps in Process Selection


AGC-AVLIS Technical Review Proponent
Technology Assessment Contractor
Business & Market Analyses Contractor
DOE Panel
Deciding Official
Initial Critiques
Final Critiques
AGC-AVLIS Assessment Methodology
Detailed Assessment
Final Assessment
Preliminary Evaluation
Detailed Evaluation
Issue Evaluation Criteria
Initial Review
Review & Evaluation
Recommendation
Process Selection
6/84
1/85
Mid 85

What this chart shows, Madam Chairman, the dotted line, dashed line, shows the operating cost to fund that total strategy. If we were to fund two technologies through full demonstration through 1987, were we to build an eight-building GCEP, and were we to operate the three gaseous diffusion plants at a high power level sufficient to meet the higher estimated demands, we would require that revenue stream there to fund our outlays, slightly over $2.6 billion. In fact, the revenues that we see in that timeframe, due to deferrals of reactors and due to the secondary market, is nearly $1 billion less than that.

So, faced with that, we drew two conclusions. One is that the revenues would not be adequate to fund the prior program, which in certain years would require us in the late 1980's to spend nearly 20 percent of our total revenues on R&D.

To show you the percentage of research and development, to give you an indication of the percent of research and development that other industries currently are spending, both high-tech and low technology, we are funding in 1982—we were in our 1982 program—9.4 percent of our total sales in R&D expenses. You can see that that is higher than any other businesses with a much more firm and vigorous market share, so we—given the amount of money we were spending on research and development in the current plan and available revenues, we concluded that it was appropriate for us to rescope the research and development program to live within those revenues but at the same time not to lose any of the promise of either advanced technology.

So, in summary, what we are doing is, in fiscal year 1985 we will select between the two technologies prior to funding both to a point of full, full-up demonstration. We will choose which of the two technologies in mid-fiscal year 1985 in which we will put most of our resources to carry through demonstration and which to carry as a backup. It does not diminish our commitment to advanced technologies, and it certainly does not cause us to make a decision before we have a good data base in hand, but it does assure that we can focus and assure that we have one good technology, rather than spreading very limited resources over two programs and ending up with one of our competitors passing us and introducing the advanced technology before we can.

Mrs. LLOYD. If you do terminate one of the technologies, will you use fiscal year 1985 funds to terminate a program, if you reach this decision?

Mr. LONGENECKER. Both of the programs are paced such that within the available funds they could be closed out with those funding levels, $72 and $78 million respectively, in 1985. If for some unforeseen reason that can't be done, we would stretch it so that we could live within those funds and pay the remainder of the termination in fiscal year 1986.

Mrs. LLOYD. Well, if your ultimate goal is to close down 27 million SWU's gaseous diffusion capacity, then why doesn't it make sense to build a four-building, 13 million SWU GCEP with AGC, and then after this build a 14 million SWU AVLIS plant?

Mr. LONGENECKER. Madam Chairman, any new capacity that we build, of course, is built for the sole purpose of reducing price to our customers, because a gaseous diffusion plant currently produces SWU's at slightly under $100 per SWU operating cost, so we need to get a way of lowering the price. We are using, as Dr. Brewer said, less than 40 percent currently, about 35 percent next year, of that available capacity, so we do need some replacement capacity but the amount we need is driven by the response to the new contract. As I said, it will give us 10 years forward estimates of revenues and sales and, based on that, in late calendar year 1984 we can determine which of the GDP's that we could retire, if any, and how much GCEP or other advanced technology capacity we would need and in what timeframe. Today, as Mr. Walker said, until we see the response to the contract we don't have a firm enough market to commit to building that much capacity, but we are not anticipating at this time that we would in the 1990's need on the order of 27 million SWU's.

Mrs. **Lloyd**. I think we should just take advantage of hindsight and not close out future customers by not looking to have the capacity in the future.

Mr. **Brewer**. That's our philosophy also, Madam Chairman. The crisis that we are up against now is getting our customers back. It's a market problem, and one of the tools that we are using to lure customers to convert is the pricing stability, the predictability of our price. Now we have to achieve economies in order to stay within that ceiling.

Mrs. **Lloyd**. Well, do you feel that you are operating this enrichment enterprise as a business would be operated in the private sector?

Mr. **Brewer**. The first thing a business would do is to secure its market and to respond to its market, and that's precisely what we are doing. We would like to do a lot more in the research and development area and the deployment of new technologies, but the percentage that we are spending on research and development and on the future is comparable to what the private sector would do. In fact, it is more, as Mr. Longenecker has indicated, about 9 percent versus about 5 percent.

Mrs. **Lloyd**. Well, you are operating under the constraint that expenditures will not be greater than revenue.

Mr. **Brewer**. That's correct.

Mrs. **Lloyd**. It seems to me that, especially when you have such a long time in planning for customers, that no real prudent business would plan capital expenditure without borrowing. Now perhaps the enrichment business ought to be put on a revolving fund with more borrowing capacity. Have you thought about that?

Mr. **Longenecker**. Madam Chairman, in our statement we note that one of our primary objectives in fiscal year 1985 is, following the firming up of the market with a new contract, to bring into being and make a recommendation to the Congress in concert with the fiscal year 1986 budget, various alternatives for obtaining funds for new capital construction from a non-Federal outlay source. We are currently evaluating with various organizations in the private sector different schemes for that, and it certainly is our intent. That allows us to have much better control over the construction projects. It, as you point out, allows us to fund our new capital construction in a way similar to the way business does, and to assure that we do not burden today's ratepayers in the rate structure with the very high cost of capital construction for which they may get no benefit in the future. We see major advantages here, and we will be evaluating that vigorously in fiscal year 1984 and 1985.

Mrs. LLOYD. It does seem to me that it would be a better and more prudent business decision in the enrichment business.

FIGURE 5

UNIT COSTS OF PRODUCTION - $/SWU

	GCEP Set V Centrifuges		
	2 Bldgs.	4 Bldgs.	AVLIS
Full Cost (FY 85 $)	$100	$ 62	$ 25
Incremental Cost (FY 85 $)	57	40	25
ESC to 1996 at 9%	102	70	55
TEC FY 85 $ in Billions			
Full	$4.65	$5.96	$1.49
Incremental	$2.24	$3.55	$1.49

NOTE: Assumes interest rate of 9 percent, 25-year plant life, and straight-line depreciation.

Mr. Longenecker, would you please provide us, also, with a chart for the record using four buildings (figure 5), using only set V machines, as well?

Mr. **Longenecker**. Yes, Madam Chairman.

Mrs. **Lloyd**. Thank you very much for your testimony, and we will be submitting additional questions for the record. We thank you. If there is no further business, the committee is adjourned.

[Whereupon, at 1:50 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

1985 DEPARTMENT OF ENERGY AUTHORIZATION

TUESDAY, FEBRUARY 28, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
Washington, D.C.

The subcommittee met, pursuant to the order of the Chair, at 9 a.m., in room 2325, Rayburn House Office Building, Hon. Marilyn Lloyd (chairman of the subcommittee) presiding.

Present: Representatives Lloyd, Valentine, and Walker.

Staff present: John V. Dugan, staff director; Louis Ventre, Jr., counsel; Bill Harvey, minority energy coordinator; and David Clement, minority counsel.

Mrs. Lloyd. The Subcommittee on Energy Research and Production will come to order. Good morning, ladies and gentlemen. This morning the subcommittee will receive testimony from national laboratory and non-DOE witnesses on the administration's proposed fiscal year 1985 budget for the uranium enrichment program. We heard the Department's justification of its request last Tuesday. I won't repeat all of the concerns that were mentioned during the last hearing, but I will say that this program faces rough times in the future. Without leadership today, we could well be confronted with the prospects of a failing business just when we need it most to insure continued economic prosperity, national security, and the reputation of a reliable nuclear supplier. The enrichment enterprise needs a much less expensive method for providing its services than the present gaseous diffusion plants. There are two technologies that promise us reduced costs, laser and advanced centrifuge separation, but there is very little capital to support this research. We are confronted with a need to make prudent judgments on how rapidly to develop these technologies, and we are asking for the advice of those who know best to help us make these determinations. Our first panel today will consist of Mr. Charles Rowan from Garrett Corp.; Mr. Richard Grant from Boeing Engineering & Construction Co., a familiar face and he's a very valuable constituent of mine in the Third District of Tennessee; and Dr. E. O. Hartig from Goodyear Aerospace Corp. These gentlemen represent the manufacturers of centrifuge machines and developers of advanced centrifuge technology, and I know they will be able to provide the subcommittee with their insight on the merits of this technology. And before we ask this panel to begin, I would like to ask if the ranking Republican member has testimony he would like—Mr.

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Walker as well as Mr. Winn, without objection, their opening remarks will be made a part of the record.

[The opening statements of Mr. Winn and Mr. Walker follow:]

OPENING STATEMENT

THE HONORABLE LARRY WINN, JR.

ENERGY RESEARCH AND PRODUCTION SUBCOMMITTEE
HEARING ON URANIUM ENRICHMENT
FEBRUARY 28, 1984

MADAME CHAIRMAN, I WELCOME THIS OPPORTUNITY TO RECEIVE TESTIMONY FROM WITNESSES OUTSIDE THE DEPARTMENT OF ENERGY ON THE URANIUM ENRICHMENT PROGRAM.

WE ARE ALL WELL AWARE OF THE FACT THAT THE URANIUM ENRICHMENT PROGRAM HAS HISTORICALLY MAINTAINED EXPENDITURES BELOW OR AT ANTICIPATED REVENUES EACH YEAR. EXPENDITURES INCLUDE NOT ONLY THE COST OF LABOR AND MATERIALS FOR PROVIDING THE URANIUM ENRICHMENT SERVICE BUT ALSO THE RESEARCH AND DEVELOPMENT EXPENSE.

THE DOE PLAN FOR FY1985 INCLUDES THE CONTINUED OPERATION OF ALL THREE GASEOUS DIFFUSION PLANTS. ANY DROP IN PRODUCTION RATE WILL NOT SEE A SIMILAR DROP IN OPERATING EXPENSE. THEREFORE, WE NOTE A MUCH GREATER PERCENT REDUCTION IN RESEARCH AND

DEVELOPMENT THAN IN PROGRAM REVENUES. IT IS HOPED THAT WE CAN GO FORWARD WITH THE SAME AMOUNT OF VIGOR IN OUR R&D PROGRAM AS WE HAVE APPLIED TO IT IN PREVIOUS YEARS. HOWEVER, THIS IS GOING TO CALL FOR MORE STRINGENT UTILIZATION OF AVAILABLE FUNDING. FOR EXAMPLE, WITH THE DEVELOPMENT OF THE "SET III (THREE)" CENTRIFUGE, WE MIGHT OBTAIN SOME ECONOMIES THROUGH FIXED COST PROCUREMENT OF FUTURE MACHINES. ANY SAVING THERE WOULD ENABLE US TO SPEND MORE ON LESS IMMEDIATE R&D PROJECTS, SUCH AS THE SET V MACHINE AND LASER ISOTOPE SEPERATION.

AS I MENTIONED LAST WEEK WHEN WE RECEIVED TESTIMONY FROM THE DEPARTMENT OF ENERGY ON THIS PROGRAM, WE ARE IN A COMPETITIVE MARKETING MODE. IT HAS NOT ALWAYS BEEN THIS WAY BUT I SUSPECT IT WILL BE IN THE FUTURE. WE CERTAINLY WANT TO MAINTAIN MARKET SENIORITY, AT LEAST. THIS WILL CALL FOR A CONCERTED EFFORT FROM ALL THE PARTICIPANTS IN THE PROGRAM.

AGAIN, MADAME CHAIRMAN, I AM CERTAIN THIS HEARING TODAY WILL BE VERY HELPFUL TO US IN OUR CONSIDERATION OF THE FY1985 URANIUM ENRICHMENT BUDGET.

THANK YOU.

OPENING REMARKS

REPRESENTATIVE ROBERT S. WALKER

FEBRUARY 28, 1984

GOOD MORNING, MADAME CHAIRMAN, I WOULD LIKE TO JOIN YOU IN WELCOMING OUR WITNESSES BEFORE THE SUBCOMMITTEE THIS MORNING. OUR TOPIC, URANIUM ENRICHMENT, IS ONE WHICH I BELIEVE NEEDS A CONSIDERABLE AMOUNT OF CONGRESSIONAL ATTENTION.

RECENTLY, WHEN ASSISTANT SECRETAPY BREWER APPEARED BEFORE THIS COMMITTEE, I SUGGESTED THAT THE DEPARTMENT SHOULD UNDERTAKE A MAJOR MARKET SURVEY OF THE FUTURE URANIUM ENRICHMENT MARKET. AT THAT TIME

HIS RESPONSE WAS THAT THE NEW DOE CONTRACT WOULD BE A STEP TOWARD A MARKET SURVEY.

WE ARE AT A POINT WHERE IN THE VERY NEAR FUTURE WE WILL HAVE TO MAKE SOME VERY SERIOUS POLICY DECISIONS ABOUT THE URANIUM ENRICHMENT PROGRAM. WITHIN THE NEXT FEW YEARS WE WILL HAVE TO DETERMINE IF THE PROGRAM SHOULD MOVE FORWARD WITH SET III OR SET V MACHINES, OR IF WE SHOULD WAIT FOR THE ATOMIC VAPOR LASER ISOTOPE SEPERATION PROCESS TO BECOME AVAILABLE. WE WILL ALSO HAVE TO MAKE FUNDEMENTAL DECISIONS CONCERNING THE PRESENT PLANTS AT OAK RIDGE, PADUCCAH, AND AT PORTSMITH.

EACH OF THESE QUESTIONS INVOLVES HUNDREDS OF JOBS, AND THE POSSIBLE EXPENDITURE OF BILLIONS OF TAXPAYER DOLLARS. WITHOUT A FULLY CREDABLE MARKET SURVEY WHICH WILL TELL US EXACTLY WHAT THE FUTURE MARKET FOR URANIUM ENRICHMENT SERVICES REALLY WILL BE, WE HAVE NO WAY TO EVEN

DETERMINE WHAT SHARE OF THAT MARKET PLACE THE UNITED STATES SHOULD AIM TO CAPTURE.

MOST OF US IN THE CONGRESS DO NOT HAVE MARKETING EXPERIENCE, BUT IT SEEMS OBVIOUS TO ME THAT NO CORPORATION WOULD UNDERTAKE CONSTRUCTION OF A MULTI-BILLION DOLLAR FACILITY WITHOUT A VERY GOOD UNDERSTANDING OF EXACTLY WHAT THE MARKET PROSPECTS FOR THEIR PRODUCT WILL BE THROUGHOUT THE LIFE OF THE PLANT. I HAVE SEEN NO EVIDENCE WHATSOEVER WHICH WOULD GIVE ME ANY INDICATION THAT DOE HAS THAT KIND OF INFORMATION ON THE URANIUM ENRICHMENT MARKETPLACE.

ACTUALLY, THIS PROGRAM GENERALLY DOES NOT GET CLOSE SCRUTINY HERE ON CAPITOL HILL BECAUSE DOE GETS NO NET APPROPRIATION FOR URANIUM ENRICHMENT SINCE OUTLAYS ARE OFF-SET BY REVENUES. BUT THE TIME HAS COME FOR THOSE OF US IN THE CONGRESS TO TAKE A CLOSE LOOK AT EACH GOVERNMENT PROGRAM. EVEN THOUGH REVENUES DO OFF-SET OUTLAYS IN THE

LONG RUN THERE IS A SUBSTANTIAL PROBABILITY THAT THE GOVERNMENT MAY HAVE TO FUND THE PROGRAM IN THE SHORT RUN AND THAT HAS COSTS WHICH MUST BE ASSOCIATED WITH THE PROGRAM.

WE ALSO MUST UNDERSTAND THAT OVER THE PAST FEW YEARS THE UNITED STATES HAS GONE FROM A WORLD MONOPOLY IN THIS MARKETPLACE TO A SITUATION TODAY WHERE WE NOW CONTROL ONLY A LITTLE MORE THAN A THIRD OF THE WORLD MARKET. PART OF THAT LOSS OF OUR MARKET CAME FROM THE AGGRESSIVE ENTRY INTO THE MARKETPLACE OF THE EUROPEANS. PART OF IT WAS CAUSED BY THE INSTABILITY OF THE NUCLEAR INDUSTRY. AND PART OF IT WAS CAUSED BY OUR INCONSISTANT ENERGY POLICY OVER THE PAST DECADE. BUT A LARGE PART OF THE CAUSE WAS BASED ON A BASIC LACK OF HARD INFORMATION UPON WHCIH TO BASE A COMPREHENSIVE MARKETING PLAN.

THIS YEAR, MADAME CHAIRMAN, I THINK THAT WE ON THE COMMITTEE WILL HAVE SOME VERY DIFFICULT CHOICES TO MAKE. WE HAVE ALREADY DONE A LOT OF

TALKING ABOUT A NEW INITIATIVE TO DEVELOP INHERENTLY SAFE REACTORS. AND I GATHERED FROM THE TESTIMONY WE HEARD LAST WEEK THAT WE WILL HAVE TO MAKE A DECISION ON THE TFCX PROGRAM IN THE IMMEDIATE FUTURE. I AM SURE THAT WE WILL ALSO FIND SOME OTHER AREAS IN WHICH WE WILL WANT TO INFLUENCE THE PROGRAMS WITHIN DOE.

IT APPEARS TO ME THAT THERE IS SUFFICIENT MONEY WITHIN THE BUDGET PROPOSED BY THE PRESIDENT TO CARRY ON A VIABLE R&D PROGRAM WITHIN DOE. IT WILL BE MY INTENTION TO GIVE THE SECRETARY OF ENERGY CONSIDERABLE FREEDOM TO MOVE FUNDS WITHIN PROGRAMS, AND I WOULD ALSO LIKE TO OFFER THE SECRETARY THE OPPORTUNITY TO SUBMIT HIS VIEWS ON THOSE AREAS IN WHICH HE FEELS THAT SOME MODIFICATIONS SHOULD BE MADE IN THE BUDGET BASED ON THE HEARINGS WE HAVE HELD IN RECENT WEEKS.

ONE OF THE MOST DIFFICULT THINGS WE MUST DO AROUND HERE IS TO TAKE RESPONSIBILITY FOR THE SPENDING WE AUTHORIZE. THERE ARE MANY IMPORTANT PROJECTS, AND MANY MERITORIOUS PROGRAMS, EACH OF WHICH MIGHT SHOW IMPRESSIVE RESULTS IF WE COULD ONLY PROVIDE MORE FUNDING FOR THE RESEARCH RIGHT NOW. BUT WE MUST KEEP IN MIND THAT THE DEFICIT FACING THE AMERICAN TAXPAYER IS BUILT ONE STEP AT A TIME. EACH ADD-ON SEEMS SO INNOCUOUS BY ITSELF. BUT TOGETHER THEY ADD UP, AND AS THE LATE EVERITT DIRKSEN USED TO SAY, "A BILLION HERE, A BILLION THERE, PRETTY SOON YOU'RE TALKING REAL MONEY!"

Mrs. Lloyd. Gentlemen, you may proceed. Welcome.

STATEMENT OF CHARLES ROWAN, DIRECTOR OF ENRICHMENT SYSTEMS, AIRESEARCH MANUFACTURING CO., A DIVISION OF THE GARRETT CORP., A SIGNAL COMPANY, ACCOMPANIED BY JEFF EAGLESON, WASHINGTON OFFICE, AND LARRY HUPPERT, TORRENCE, CALIF. OFFICE

Mr. Rowan. Thank you. Would you like me to——

Mrs. Lloyd. Yes, Mr. Rowan.

Mr. Rowan. Madam Chairman and members of this subcommittee, I am Charles Rowan, director of enrichment systems for Airesearch Manufacturing Co., a division of the Garrett Corp., which is one of the Signal companies. Accompanying me today are Jeff Eagleson from our Garrett Washington office and Mr. Larry Huppert from our Torrence, Calif., plant. Gas centrifuge development and production activities have been a significant part of Garrett's 23-year history of participation in enrichment enterprise activities. The corporation, as you may know, is a world leader in engineering and production of high-speed rotating equipment. This background provides unique qualifications for gas centrifuge engineering and manufacturing requirements. Presently, nearly 1,000 people are employed in our corporation, supporting gas centrifuge-related activities at locations in California, Ohio, and Tennessee.

Your February 15 letter of invitation to testify before the subcommittee requested comments on the DOE centrifuge program objectives, schedules, fiscal year 1985 budget proposal, and purchase rates for set III centrifuge machines, if only a two- or four-building gas centrifuge enrichment plant is built. First, we would like to comment favorably on the exceptional effort put forth by the Department of Energy to improve significantly the contract terms and pricing offered to domestic and foreign utility customers under the provisions of the new utility services toll enrichment contract.

It is a reflection of the Department's vigorous attention to a strong marketing approach in the conduct of the enrichment enterprise affairs. Garrett also wholeheartedly endorses the current DOE objective to continue counting on GCEP, the gas centrifuge enrichment plant at Portsmouth, Ohio, as the next increment in an enrichment plant modernization program for the United States. It is a key building block in DOE's plan to regain U.S. leadership as a reliable supplier of uranium-enrichment services to the world.

Simultaneously, aggressive pursuit of the set V advanced gas centrifuge model technology, building upon the solid technological base already demonstrated in set III, is endorsed. These two major thrusts maximize the probability of achieving DOE's ultimate objective to convince many currently disenchanted potential buyers of toll-enrichment service that the United States can, indeed, be counted upon to provide such service in a timely manner and at competitive price. Current schedules for developing and deploying set V centrifuge are tight, but achievable if properly funded. The DOE 1985 requested level of funding for development and follow-on evaluation testing of the set V machine is considered marginal. Additional funds should be allocated to this effort to take maximum advantage of the great potential for reduction in cost of separative work which set V technology represents.

Furthermore, Garrett strongly recommends action be taken to assure that any additional centrifuge development and testing funds, and those funds already slated for this purpose, be allocated primarily to support work by those program participants who have the most at stake in the success of the centrifuge program; namely, the centrifuge manufacturers. Progress in developing set V technology has already exceeded expectations, thereby providing early justification of high confidence on the part of DOE and all program participants in meeting performance goals.

A keystone in meeting these goals has been the successful application of an advanced material for centrifuge rotor construction. Whereas early in the program it was anticipated that a significant development program would be required to learn how to work with this new material, early experience, not only at Garrett but among all program participants, has shown that fabrication techniques very successfully employed with the set III material are almost directly applicable to the AGC set V. Centrifuges incorporating the new material are already providing valuable development feedback with respect to both the new rotor material and the suspension system designs required for providing dynamic control of the rotor. Garrett recognizes the desirability of bringing along other promising separation technologies such as the atomic vapor laser isotope separation process, or AVLIS.

However, when confronted with the currently projected enrichment services revenue shortfall, DOE should give serious consideration to allocating the larger portion of any available R&D funds to support set V technology development because it is currently on the steep part of the technological progress curve and could, if properly funded, provide the most rapid demonstration to the enrichment services marketplace that the United States will be able to deliver the hoped-for low-cost separative work.

Although AVLIS may have long-term potential, yet to be demonstrated, early confidence-building AVLIS demonstrations of the type needed to attract new enriching customers are, in our opinion, not likely in the critical near term. Garrett supports early introduction of the set V machine and believes that pilot production can be initiated in the 1986 timeframe. All three manufacturers will be needed in the program under their existing cost contracts for meaningful completion of vital AGC design and process development work which would then permit the Department of Energy to convert to the set V configuration for full production.

This collective expertise is a true DOE national asset, representing a $300-million investment by the Government and a $185-million investment on the part of the centrifuge manufacturers who have now established a 15-year developed base of proven technology in production manufacturing processes and vendor networks. The collective capabilities represented by the three suppliers would be impossible to recreate in 2 or 3 years if interrupted. There is a very definite value in sustaining production continuity until the AGC is ready.

Uninterrupted manufacturing maintains CM facilities and personnel in a highly productive mode, efficiently supports a cleared vendor base, and provides support for the requisite GCEP infrastructure, including process plant operations at Portsmouth as well as recycle and assembly facility operations there, all of which are functionally essential to achieving a successful and viable AGC technology base.

Such a plan also places the centrifuge manufacturers in a position of readiness for a key set V competition with three qualified sources when the program ramps up; fixed price procurement of centrifuge machines should not occur until that ramp-up takes place. To have a meaningful fixed price competition, there needs to be a significant increase in production rates for an adequately demonstrated and documented design.

Furthermore, DOE has expressed interest in achieving off-budget status for enrichment activities. This goal may be achievable, although quite difficult, in our view, in the timeframe planned. However, it would surely be in the Government's best interest to maintain maximum industry participation in GCEP in order to enhance that probability. If privatization in some form or for some segment of the enrichment enterprise is involved to attain off-budget objectives, then the implementation plan adopted may well include one centrifuge manufacturer, or perhaps even all centrifuge manufacturers and others in a cooperative endeavor.

The DOE plan for a sharply reduced set III production rate brings Garrett to the minimum quantity that can support any kind of meaningful basic manufacturing skill and process equipment operation on a continuing basis. Obviously, it would be much more efficient to continue production of the set III machines at the present rate, bringing GCEP process building No. 1 on line as soon as possible, and leading the way to reducing dependence on the gaseous diffusion plants with their high rate of energy consumption.

We understand DOE's desire to remain in a zero appropriations position, and we agree with their goal to make a decision between the advanced technologies as soon as possible in 1985. We also believe that the centrifuge manufacturers are key in bringing the AGC online in an expeditious fashion. It is our judgment, therefore, that the most cost-effective program overall would be to do these things:

No. 1, continue set III production at current rates, avoiding degradation in the manufacturing proficiency as well as a significant loss of jobs.

Second, accelerate the AGC program with whatever funds are available and bring it online for a four-building GCEP.

Third, develop AVLIS at a sufficient rate for introduction as a next-generation enrichment process after it has proven itself in a sustained, end-to-end system mode under a rigorous test program designed to demonstrate conclusively its economic viability.

Fourth, provide budget stability so that DOE and its supporting contractors can avoid erratic actions that may be driven by short-term cost-saving goals imposed at the expense of long-term survivability of the U.S. enrichment enterprise.

Last, Madam Chairman, we would like to again express our praise for DOE's concerted effort to improve the terms and conditions in their toll enrichment services contracts. Recognition of urgent customer needs is always essential in selling a product or service.

We would encourage the Congress to support DOE in its continuing search for even more flexible SWU marketing, pricing, and contracting policies. We also believe that a greater sense of urgency in adopting a specific set of milestones for turning down all three energy-intensive diffusion plants is needed, together with an action plan for resolving the TVA demand charge issue.

We are confident Congress shares both industry's and DOE's view that energy self-sufficiency is a major priority for all of us and that adoption of this national goal for nuclear fuel supply, even if it should imply departure from the current zero appropriations philosophy, will prevent the emergency of an OPEC-like situation in enrichment when we have the technology and industrial resources in hand to preclude such a development from ever occurring.

We believe that our people at Garrett can help substantially in implementing a vigorous revitalization of the U.S. enterprise through aggressive application of its advanced centrifuge technology as well as its will and determination to support a DOE and congressional leadership team dedicated to a strong, competitive, and long-lived U.S. enrichment enterprise. The Garrett Corp. appreciates the opportunity you have provided today to express our views on the program, the centrifuge program, and the overall U.S. enrichment enterprise.

[The prepared statement of Mr. Rowan follows:]

STATEMENT OF THE GARRETT CORPORATION
AT THE MARILYN LLOYD HEARING
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY

MADAM CHAIRMAN AND MEMBERS OF THIS SUBCOMMITTEE, I AM CHARLES ROWAN, DIRECTOR OF ENRICHMENT SYSTEMS FOR AIRESEARCH MANUFACTURING COMPANY, A DIVISION OF THE GARRETT CORPORATION, WHICH IS ONE OF THE SIGNAL COMPANIES. I AM ACCOMPANIED TODAY BY WILLIS SULLIVAN, MANAGER OF GARRETT'S WASHINGTON, D. C. OFFICE.

GAS CENTRIFUGE DEVELOPMENT AND PRODUCTION ACTIVITIES HAVE BEEN A SIGNIFICANT PART OF OUR 23-YEAR HISTORY OF PARTICIPATION IN ENRICHMENT ENTERPRISE ACTIVITIES. THE GARRETT CORPORATION, AS YOU MAY KNOW, IS A WORLD LEADER IN ENGINEERING AND PRODUCTION OF HIGH-SPEED ROTATING EQUIPMENT. THIS BACKGROUND PROVIDES UNIQUE QUALIFICATIONS FOR GAS CENTRIFUGE ENGINEERING AND MANUFACTURING REQUIREMENTS. PRESENTLY, NEARLY 1000 PEOPLE ARE EMPLOYED IN OUR CORPORATION, SUPPORTING GAS CENTRIFUGE-RELATED ACTIVITIES AT LOCATIONS IN CALIFORNIA, OHIO AND TENNESEE.

YOUR FEBRUARY 15, 1984 LETTER OF INVITATION TO TESTIFY BEFORE THE SUBCOMMITTEE REQUESTED COMMENTS ON THE DOE CENTRIFUGE PROGRAM OBJECTIVES, SCHEDULES, FY 1985 BUDGET PROPOSAL, AND PURCHASE RATES FOR SET III CENTRIFUGE MACHINES, IF ONLY A TWO OR FOUR-BUILDING GAS CENTRIFUGE ENRICHMENT PLANT IS BUILT.

FIRST, WE WOULD LIKE TO COMMENT FAVORABLY ON THE EXCEPTIONAL EFFORT PUT FORTH BY DOE TO IMPROVE SIGNIFICANTLY THE CONTRACT TERMS AND PRICING OFFERED TO DOMESTIC AND FOREIGN UTILITY CUSTOMERS UNDER THE PROVISIONS OF THE NEW UTILITY SERVICES ("U.S.") TOLL ENRICHMENT CONTRACT. IT IS A REFLECTION OF THE DEPARTMENT'S VIGOROUS ATTENTION TO A STRONG MARKETING APPROACH IN THE CONDUCT OF THE ENRICHMENT ENTERPRISE AFFAIRS.

GARRETT ALSO WHOLEHEARTEDLY ENDORSES THE CURRENT DOE OBJECTIVE TO CONTINUE COUNTING ON GCEP, THE GAS CENTRIFUGE ENRICHMENT PLANT AT PORTSMOUTH, OHIO, AS THE NEXT INCREMENT IN AN ENRICHMENT PLANT MODERNIZATION PROGRAM FOR THE UNITED STATES. IT IS A KEY BUILDING BLOCK IN DOE'S PLAN TO REGAIN U. S. LEADERSHIP AS A RELIABLE SUPPLIER OF URANIUM ENRICHMENT SERVICES TO THE WORLD. SIMULTANEOUSLY, AGGRESSIVE PURSUIT OF THE SET V ADVANCED GAS CENTRIFUGE (AGC) MODEL TECHNOLOGY, BUILDING UPON THE SOLID TECHNOLOGICAL BASE ALREADY DEMONSTRATED IN SET III, IS ENDORSED. THESE TWO THRUSTS MAXIMIZE THE PROBABILITY OF ACHIEVING DOE'S ULTIMATE OBJECTIVE TO CONVINCE MANY CURRENTLY DISENCHANTED POTENTIAL BUYERS OF TOLL ENRICHMENT SERVICE THAT THE UNITED STATES CAN INDEED BE COUNTED UPON TO PROVIDE SUCH SERVICE IN A TIMELY MANNER AT A COMPETITIVE PRICE.

CURRENT SCHEDULES FOR DEVELOPING AND DEPLOYING THE SET V CENTRIFUGE ARE TIGHT, BUT ACHIEVABLE IF PROPERLY FUNDED. THE DOE 1985 REQUESTED LEVEL OF FUNDING FOR DEVELOPMENT AND FOLLOW-ON EVALUATION TESTING OF THE SET V MACHINE IS CONSIDERED MARGINAL. ADDITIONAL FUNDS SHOULD BE ALLOCATED TO THIS EFFORT TO TAKE MAXIMUM ADVANTAGE OF THE GREAT POTENTIAL FOR REDUCTION IN COST OF SEPARATIVE WORK WHICH SET V TECHNOLOGY REPRESENTS. FURTHERMORE, GARRETT STRONGLY RECOMMENDS ACTION BE TAKEN TO ASSURE THAT ANY ADDITIONAL CENTRIFUGE DEVELOPMENT AND TESTING FUNDS, AND THOSE FUNDS ALREADY SLATED FOR THIS PURPOSE, BE ALLOCATED PRIMARILY TO SUPPORT WORK BY THOSE PROGRAM PARTICIPANTS WHO HAVE THE MOST AT STAKE IN THE SUCCESS OF THE CENTRIFUGE PROGRAM; NAMELY, THE CENTRIFUGE MANUFACTURERS.

PROGRESS IN DEVELOPING SET V TECHNOLOGY HAS ALREADY EXCEEDED EXPECTATIONS, THEREBY PROVIDING EARLY JUSTIFICATION OF HIGH CONFIDENCE ON THE PART OF DOE AND ALL PROGRAM PARTICIPANTS IN MEETING SET V

PERFORMANCE GOALS. A KEYSTONE IN MEETING THESE GOALS HAS BEEN THE SUCCESSFUL APPLICATION OF AN ADVANCED MATERIAL FOR CENTRIFUGE ROTOR CONSTRUCTION. WHEREAS EARLY IN THE PROGRAM IT WAS ANTICIPATED THAT A SIGNIFICANT DEVELOPMENT PROGRAM WOULD BE REQUIRED TO LEARN HOW TO WORK WITH THIS NEW MATERIAL, EARLY EXPERIENCE NOT ONLY AT GARRETT BUT AMONG ALL PROGRAM PARTICIPANTS HAS SHOWN THAT FABRICATION TECHNIQUES VERY SUCCESSFULLY EMPLOYED WITH THE SET III MATERIAL ARE ALMOST DIRECTLY APPLICABLE TO THE AGC SET V. CENTRIFUGES INCORPORATING THE NEW MATERIAL ARE ALREADY PROVIDING VALUABLE DEVELOPMENT FEEDBACK WITH RESPECT TO BOTH THE NEW ROTOR MATERIAL AND THE SUSPENSION SYSTEM DESIGNS REQUIRED FOR PROVIDING DYNAMIC CONTROL OF THE ROTOR.

GARRETT RECOGNIZES THE DESIRABILITY OF BRINGING ALONG OTHER PROMISING SEPARATION TECHNOLOGIES SUCH AS THE ATOMIC VAPOR LASER ISOTOPE SEPARATION (AVLIS) PROCESS. HOWEVER, WHEN CONFRONTED WITH THE CURRENTLY PROJECTED ENRICHMENT SERVICES REVENUE SHORTFALL, DOE SHOULD GIVE SERIOUS CONSIDERATION TO ALLOCATING THE LARGER PORTION OF ANY AVAILABLE R&D FUNDS TO SUPPORT SET V TECHNOLOGY DEVELOPMENT BECAUSE IT IS CURRENTLY ON THE STEEP PART OF THE TECHNOLOGICAL PROGRESS CURVE AND COULD, IF PROPERLY FUNDED, PROVIDE THE MOST RAPID DEMONSTRATION TO THE ENRICHMENT SERVICES MARKETPLACE THAT THE UNITED STATES WILL BE ABLE TO DELIVER THE HOPED-FOR LOW-COST SEPARATIVE WORK. ALTHOUGH AVLIS MAY HAVE LONG TERM POTENTIAL (YET TO BE DEMONSTRATED) EARLY CONFIDENCE BUILDING AVLIS DEMONSTRATIONS OF THE TYPE NEEDED TO ATTRACT NEW ENRICHING CUSTOMERS ARE NOT LIKELY IN THE CRITICAL NEAR TERM.

GARRETT SUPPORTS EARLY INTRODUCTION OF THE SET V MACHINE AND BELIEVES THAT PILOT PRODUCTION CAN BE INITIATED IN THE 1986 TIMEFRAME. ALL THREE MANUFACTURERS WILL BE NEEDED IN THE PROGRAM UNDER THEIR EXISTING COST CONTRACTS FOR MEANINGFUL COMPLETION OF VITAL AGC DESIGN AND PROCESS DEVELOPMENT WORK WHICH WOULD THEN PERMIT DOE TO CONVERT TO THE SET V CONFIGURATION FOR FULL PRODUCTION. THIS COLLECTIVE EXPERTISE IS A TRUE DOE NATIONAL ASSET, REPRESENTING A $300,000,000 INVESTMENT BY DOE AND A $185,000,000 INVESTMENT ON THE PART OF THE CENTRIFUGE MANUFACTURERS, WHO HAVE NOW ESTABLISHED A 15-YEAR DEVELOPED BASE OF PROVEN TECHNOLOGY IN PRODUCTION MANUFACTURING PROCESSES AND VENDOR NETWORKS. THE collective CAPABILITIES REPRESENTED BY THE THREE SUPPLIERS WOULD BE IMPOSSIBLE TO RECREATE IN TWO OR THREE YEARS IF INTERRUPTED.

THERE IS A VERY DEFINITE VALUE IN SUSTAINING PRODUCTION CONTINUITY UNTIL THE AGC IS READY. UNINTERRUPTED MANUFACTURING MAINTAINS CM FACILITIES AND PERSONNEL IN A HIGHLY PRODUCTIVE MODE, EFFICIENTLY SUPPORTS A CLEARED VENDOR BASE, AND PROVIDES SUPPORT FOR THE REQUISITE GCEP INFRASTRUCTURE, INCLUDING PROCESS PLANT OPERATIONS AS WELL AS RECYCLE AND ASSEMBLY FACILITY OPERATIONS, ALL OF WHICH ARE FUNCTIONALLY ESSENTIAL TO ACHIEVING A SUCCESSFUL AND VIABLE AGC TECHNOLOGY BASE. SUCH A PLAN ALSO PLACES THE CENTRIFUGE MANUFACTURERS IN A POSITION OF READINESS FOR A KEY SET V COMPETITION WITH THREE QUALIFIED SOURCES WHEN THE PROGRAM RAMPS UP. FIXED PRICE PROCUREMENT OF CENTRIFUGE MACHINES SHOULD NOT OCCUR UNTIL THAT RAMP-UP TAKES PLACE. TO HAVE A MEANINGFUL FIXED PRICE COMPETITION, THERE NEEDS TO BE A SIGNIFICANT INCREASE IN PRODUCTION RATES FOR AN ADEQUATELY DEMONSTRATED AND DOCUMENTED DESIGN. FURTHERMORE, DOE HAS EXPRESSED INTEREST IN ACHIEVING

"OFF BUDGET" STATUS FOR ENRICHMENT ACTIVITIES. THIS GOAL MAY BE ACHIEVABLE, ALTHOUGH QUITE DIFFICULT IN OUR VIEW IN THE TIME FRAME PLANNED; HOWEVER, IT WOULD SURELY BE IN THE GOVERNMENT'S BEST INTEREST TO MAINTAIN MAXIMUM INDUSTRY PARTICIPATION IN GCEP IN ORDER TO ENHANCE THAT PROBABILITY. IF PRIVATIZATION IN SOME FORM OR FOR SOME SEGMENT OF THE ENRICHMENT ENTERPRISE IS INVOLVED TO ATTAIN "OFF BUDGET" OBJECTIVES, THEN THE IMPLEMENTATION PLAN ADOPTED MAY WELL INCLUDE ONE CENTRIFUGE MANUFACTURER OR PERHAPS EVEN ALL CENTRIFUGE MANUFACTURERS AND OTHERS IN A COOPERATIVE ENDEAVOR.

THE DOE PLAN FOR A SHARPLY REDUCED SET III PRODUCTION RATE BRINGS GARRETT TO THE MINIMUM QUANTITY THAT CAN SUPPORT ANY KIND OF MEANINGFUL BASIC MANUFACTURING SKILL AND PROCESS EQUIPMENT OPERATION ON A CONTINUING BASIS. OBVIOUSLY, IT WOULD BE MUCH MORE EFFICIENT TO CONTINUE PRODUCTION OF THE SET III MACHINES AT THE PRESENT RATE, BRINGING GCEP PROCESS BUILDING NO. 1 ON LINE AS SOON AS POSSIBLE AND LEADING THE WAY TO REDUCING DEPENDENCE ON THE GASEOUS DIFFUSION PLANTS WITH THEIR HIGH RATE OF ENERGY CONSUMPTION.

WE UNDERSTAND DOE'S DESIRE TO REMAIN IN A ZERO-APPROPRIATIONS POSITION AND WE AGREE WITH THEIR GOAL TO MAKE A DECISION BETWEEN THE ADVANCED TECHNOLOGIES AS SOON AS POSSIBLE IN 1985. WE ALSO BELIEVE THAT THE CENTRIFUGE MANUFACTURERS ARE KEY IN BRINGING THE AGC ON LINE IN AN EXPEDITIOUS FASHION. IT IS OUR JUDGMENT, THEREFORE, THAT THE MOST COST EFFECTIVE PROGRAM OVERALL WOULD BE TO:

1. CONTINUE SET III PRODUCTION AT CURRENT PRODUCTION RATES, AVOIDING DEGRADATION IN THE MANUFACTURING PROFICIENCY AS WELL AS A SIGNIFICANT LOSS OF JOBS;

2. ACCELERATE THE AGC PROGRAM WITH WHATEVER FUNDS ARE AVAILABLE AND BRING IT ON-LINE FOR A FOUR-BUILDING GCEP;
3. DEVELOP AVLIS AT A SUFFICIENT RATE FOR INTRODUCTION AS A NEXT-GENERATION ENRICHMENT PROCESS AFTER IT HAS PROVEN ITSELF IN A SUSTAINED END-TO-END SYSTEM MODE UNDER A RIGOROUS TEST PROGRAM DESIGNED TO DEMONSTRATE CONCLUSIVELY ITS ECONOMIC VIABILITY;
4. PROVIDE BUDGET STABILITY SO THAT DOE AND ITS SUPPORTING CONTRACTORS CAN AVOID ERRATIC ACTIONS THAT MAY BE DRIVEN BY SHORT-TERM COST SAVING GOALS IMPOSED AT THE EXPENSE OF LONG-TERM SURVIVABILITY OF THE U.S. ENRICHMENT ENTERPRISE.

LASTLY, MADAM CHAIRMAN, WE WOULD LIKE TO AGAIN EXPRESS OUR PRAISE FOR DOE'S CONCERTED MANAGERIAL EFFORT TO IMPROVE THE TERMS AND CONDITIONS IN THEIR TOLL ENRICHMENT SERVICES CONTRACTS. RECOGNITION OF URGENT CUSTOMER NEEDS IS ALWAYS ESSENTIAL IN SELLING A PRODUCT OR SERVICE. WE WOULD ENCOURAGE THE CONGRESS TO SUPPORT DOE IN ITS CONTINUING SEARCH FOR EVEN MORE FLEXIBLE SWU MARKETING, PRICING AND CONTRACTING POLICIES. WE ALSO BELIEVE THAT A GREATER SENSE OF URGENCY IN ADOPTING A SPECIFIC SET OF MILESTONES FOR TURNING DOWN ALL THREE ENERGY-INTENSIVE GASEOUS DIFFUSION PLANTS IS NEEDED, TOGETHER WITH AN ACTION PLAN FOR RESOLVING THE TVA DEMAND CHARGE ISSUE.

WE ARE CONFIDENT CONGRESS SHARES BOTH INDUSTRY'S AND DOE'S VIEW THAT ENERGY SELF-SUFFICIENCY IS A MAJOR PRIORITY FOR ALL OF US AND THAT ADOPTION OF THIS NATIONAL GOAL FOR NUCLEAR FUEL SUPPLY, EVEN IF IT SHOULD IMPLY DEPARTURE FROM THE CURRENT ZERO

APPROPRIATIONS PHILOSOPHY, WILL PREVENT THE EMERGENCE OF AN OPEC-LIKE SITUATION IN ENRICHMENT WHEN WE HAVE THE TECHNOLOGY AND INDUSTRIAL RESOURCES IN HAND TO PRECLUDE SUCH A DEVELOPMENT FROM EVER OCCURRING. WE BELIEVE THAT OUR PEOPLE AT GARRETT CAN HELP SUBSTANTIALLY IN IMPLEMENTING A VIGOROUS REVITALIZATION OF THE U. S. ENTERPRISE THROUGH AGGRESSIVE APPLICATION OF ITS ADVANCED CENTRIFUGE TECHNOLOGY AS WELL AS ITS WILL AND DETERMINATION TO SUPPORT A DOE AND CONGRESSIONAL LEADERSHIP TEAM DEDICATED TO A STRONG, COMPETITIVE AND LONG-LIVED U.S. ENRICHMENT ENTERPRISE.

THE GARRETT CORPORATION APPRECIATES THE OPPORTUNITY YOU HAVE PROVIDED FOR US TODAY TO EXPRESS OUR VIEWS ON THE CENTRIFUGE PROGRAM AND THE OVERALL U. S. ENRICHMENT ENTERPRISE.

Mrs. Lloyd. Thank you very much, Mr. Rowan, for a very well-prepared and well-presented statement. We're looking forward now to hear from Mr. Grant.

STATEMENT OF RICHARD L. GRANT, PRESIDENT, BOEING ENGINEERING CO. SOUTHEAST, INC., OAK RIDGE, TENN.

Mr. Grant. Thank you, Madam Chairman, counsel, and staff to the committee. Thank you for asking me here today. I appreciate the opportunity. I am Richard Grant. I'm president of the Boeing Engineering Co. Southeast, headquartered in Oak Ridge, Tenn. I thank this committee at the outset for the fine work in the past on support of the DOE's uranium enrichment enterprise.

I'm here today, as in years past, because we are in the business of fabricating the set III centrifuge and because we're in the business of doing research and development, design and testing on set V and other advanced machine concepts. We have been involved in uranium enrichment in the nuclear business for 10 years. I've had the privilege of heading that for my company during that time. We have a clear vested interest in GCEP and in set V and the other advanced technologies. We have a vested interest in the form of an investment nearing $70 million in facilities and equipment, and people who number in that facility 440 at the present time. Our supplier base covers 26 States, and that adds investment and another 600 people to those employed, because of our part of the GCEP program.

Fine, reliable centrifuge machines are being built today in east Tennessee, as they are in the other suppliers' houses. They've demonstrated lifetime substantially better than predicted. Spares requirements have been reduced to a fraction of the original estimate, resulting in reduced annual operating costs for replacement, for personnel, for supplies and equipment. Target costs can now be shown to be achievable with high confidence. The manufacturing has been demonstrated to conform to the principles which govern the manufacturer of any hardware.

In abbreviated terms, they are as follows. They are not of my invention; they're common to the industry and manufacturing as a whole: First, small quantities of like hardware will have higher unit costs than large quantities. Second, initial units of a production run will cost more than the subsequent units, and the cost improvement can be sustained over very large quantities. This is commonly called learning or improvement curves. Third, disruption or delay causes cost improvement to deteriorate. Both human skills and mechanical efficiency deteriorates. Fourth, a production capability designed for a certain rate/quantity plan will be less effective at lesser rates. Fifth, if production is stopped and restarted, very significant portions of the cost improvement can be lost.

We have at present fabricated the components far in excess of 500 centrifuge machines, closer to 600 actually, and they have observed all of these principles that I have stated in abbreviated terms. The features I have described are important to the planning and cost estimating of the GCEP program. They are central to the programmatic and economic logic of the GCEP and other similar projects. Most importantly, they illustrate that set III centrifuge production provides a cost-benefit to the set V AGC program. The developmental set V hardware being tested by ourselves and others is being fabricated in the same facility on the same equipment by the same people as is the set III. Orderly transition of production from set III to set V can be accomplished without significant disruption of production, provided that set III production is maintained. The cost thus avoided, for set V manufacturing costs can be tens of millions of dollars, and, in addition, the set III machines produced can be enriching uranium in GCEP facilities that may otherwise be idle. Continued production of set III centrifuges at or near the current rate is prudent and serves the DOE enrichment enterprise well.

Improvement in the performance and cost-effectiveness of the centrifuge is clearly desirable. The current progress on set V clearly indicates what can be expected. The developmental milestones of the past year have shown that we can substantially increase the productive output of the centrifuges without sacrifice of reliability and that the schedule for achieving these improvements is better than we thought. In August of last year, we fabricated a full-size centrifuge rotor of the new materials, and in September we enriched uranium with this rotor. Since that time, we have fabricated 10 rotors of this material, and in December of last year we ran the highest speed, full-size rotor ever in the U.S. program. One-sixth scale testing of a new concept suspension system has been completed. The full-scale version of this suspension system is under a rotor in a test stand in our facilities today. A full-scale version of the set V, all the elements in place, although all developmental components, will actually enrich uranium in our facilities in November of this year. All of these events serve as useful and essential confidence builders and supply the information necessary to finalize production design. Our current plan is to have a complete, production-ready set V design in early 1986. Long-lead materials procurement will occur prior to this time for the orderly production transition previously mentioned.

I'm delighted with the progress of the set V development, and you may be assured that we will do our best to assure its earliest introduction. At the same time, I'm relatively certain we have not seen the last suggestion for further improvement in centrifuge technology. The past 6 years have demonstrated some startling progress and success. You may be assured that these opportunities will be investigated and introduced as appropriate.

Boeing has reason to understand the importance of domestic and world economic conditions on DOE's uranium enrichment picture. In my view, the best solution to the declining revenue situation is already starting in work. The new utility services contract is an important first step, and one I hope our customers will find attractive.

Beyond this, a program with continuity, clear objectives, and demonstrated commitment to provide the high confidence, cost-effective enrichment capacity is an important ingredient which our utility customers have every right to expect. The confidence and trust of our customers, coupled with reasonable and competitive prices, can restore the U.S. enrichment market share.

I believe the GCEP program and the earliest practical introduction of set V centrifuges are key elements of a high confidence strategy. GCEP represents a significant investment to date. It is on cost and on schedule, and the private sector industrial base is established. Incremental expansion of centrifuge capacity is prudent, provided that there is sufficient decision leadtime for each next increment. The planning should go forward for at least four buildings of GCEP, and the planning should also not preclue subsequent buildings.

I am not qualified to address the various alternative financing schemes under consideration, but recommend that they be carefully considered and coordinated between the DOE and the Congress, the utilities and the private sector. Experience suggests the most credible and workable plans will tend to come from those who must implement them and those who have something substantive at stake.

Summarizing these points and a few others perhaps, we believe that the set III centrifuge program is doing everything promised and that GCEP is an outstanding success. We believe the set V program is sound, has demonstrated its technical promise, and will be ready as planned with full, actual operational demonstration. We believe that the most cost-effective centrifuge program should transition from set III to set V centrifuge production in a nondisruptive manner. We believe that centrifuge development beyond set V is both reasonable and proper. We understand the current marketplace pressures DOE is experiencing and believe that their efforts to cope with it are prudent. Customer and supplier interactions are good business in these conditions. We have consistently felt—and I have consistently said—that the maturity of the centrifuge demonstration did not warrant a technology competition, but that continued work on the other advanced technologies was prudent. We will, nonetheless, continue the development of AGC technology diligently, as we have, and make that work available to whomever DOE determines competent to assess its relative merit, on whatever schedule deemed appropriate. Finally, alternative plans for conducting the business of enrichment should be examined. They need to be coordinated and reviewed. The best should be pursued, but not without thorough assessment. The long-term implications of this are too important to do otherwise. I thank you very much

[The prepared statement of Mr. Grant follows:]

STATEMENT

MR. RICHARD L. GRANT
PRESIDENT, BOEING ENGINEERING COMPANY SOUTHEAST, INC.
OAK RIDGE, TN
before
THE SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
FEBRUARY 28, 1984

Madam Chairman, Members of the Committee; I am Richard L. Grant, President of Boeing Engineering Company Southeast, Inc., a wholly-owned subsidiary of The Boeing Company. I appreciate the opportunity to address this committee and commend you on the fine work this committee has done in support of the DOE's Uranium Enrichment enterprise.

I am here today as in years past because we are in the business of fabricating the Set III centrifuge for DOE's Gas Centrifuge Enrichment Plant (GCEP) project, and conducting research and development, design and testing of Set V Advanced Gas Centrifuges (AGC). We have been involved in the Uranium Enrichment Program for 10 years. In 1979, we along with Goodyear, Garrett and Exxon responded to DOE's Request for Proposal for the manufacture of centrifuges agreeing, as a condition for selection, to commit the skilled and experienced management and technical personnel to the program along with other corporate resources, including capital funding. We designed, built and provisioned a centrifuge manufacturing facility in Oak Ridge, Tennessee. A total of $67 million of Boeing Corporate funds is now invested in these facilities and equipment. We relocated 90 Boeing people and have hired about 350 locally. Our supplier base covers 26 states, and employment directly applicable to supply of materials and components to Boeing adds another 600 people to those employed because of our part of the program.

We have now fabricated and assembled the components for more than 500 centrifuges of the Set III type. The purpose of this first portion of the manufacturing program was to provide good quality, reliable centrifuges for installation in the Oak Ridge Demonstration Facility and GCEP and to provide manufacturing experience which demonstrated that the cost of manufacture could be reliably predicted to be within the total estimated cost at completion. Both of these purposes have been and continue to be satisfied. Fine, reliable centrifuges are being built and we can confidently predict that they will meet the cost targets.

The manufacture of centrifuges has been demonstrated to conform to the principles which govern the manufacture of almost any hardware. In very abbreviated terms these principles are:

1. Small quantities of like hardware will have higher unit costs than large quantities.
2. The initial units of a production run cost more than do the subsequent units, and the cost improvement with the manufacture of subsequent units can be sustained over very large quantities (this is commonly called learning or improvement curves).
3. Disruption or delay causes learning curve cost improvement to deteriorate (both human skill and mechanical efficiency deteriorates).
4. A production capability designed for a certain rate/quantity plan will be less cost effective at lesser rates.
5. If production is stopped and restarted, very significant portions of the cost improvement can be lost.

The above is cited to illustrate that Set III centrifuge production, in addition to providing centrifuges which do everything promised and more, provides a cost benefit to the Set V AGC Program. The Developmental Set V hardware being tested by Boeing and others is being fabricated in the same facility, on the same equipment, by the same people as the Set III. Orderly transition of production from Set III to Set V can be accomplished without significant disruption of production, provided that Set III production is maintained. The cost avoided with orderly transition can be several 10's of millions of dollars, and the Set III machines can be producing enriched uranium in GCEP facilities that may otherwise be idle. I believe that the continued production of Set III centrifuges at the current rate is prudent and serves the DOE Uranium Enrichment Enterprise objective well.

Improvement in the performance and cost effectiveness of the centrifuge is clearly desirable. Progress on Set V clearly indicates what can be expected. The developmental milestones of the past year have shown that we can substantially increase the production output of the centrifuges without sacrifice of reliability and that the schedule for achieving these improvements is better than we thought. In August of last year, we fabricated a full-size centrifuge rotor using the new materials and in September, we enriched uranium with this rotor. Since that time we have fabricated 10 rotors of those materials, and in December of last year we ran the highest speed, full-size rotor ever in the U.S. Program. One-sixth scale testing of a new concept suspension system has been completed and the full-scale version is in a test stand in our facilities today. A full-scale version of the Set V machine, although all developmental components, will begin actual enrichment demonstrations in our facilities in November of this year.

All of these events serve as useful and essential confidence builders and supply the information necessary to finalize production design details. Design activities are proceeding in parallel. The design will be proven and/or revised as these test programs indicate, culminating in the fabrication and test of a number of machines for the proof of system reliability.

Experience with the Set III machines has indicated that design modifications can proceed in parallel with production without serious disruption or compromise of the operational capability.

Our current plan is to have production-ready Set V design in early FY1986. Long-lead materials procurement will occur prior to this time for the orderly production transition previously mentioned.

Expenditures of DOE funds to date, by Boeing, for Set V development total $8.3M. The total Set V program expenditure planned by Boeing through FY1986 is $40.3M including that already spent.

I am delighted with the progress on Set V development, and you may be assured that we will do our best to assure its earliest introduction into the program. At the same time, it should be noted that I am relatively certain we have not seen the last suggestion for further improvement in centrifuge technology beyond Set V. The past six years have demonstrated great progress. You may be assured that we will investigate all opportunities for further progress and those with credible promise will be suggested and advocated.

Boeing understands the importance of domestic and world economic conditions on DOE's enrichment revenue picture. In my view, the best solution to the declining revenue situation is already in work. The new Utility Services contract is an important first step and one I hope our customers will find attractive. Beyond this, a program with continuity, clear objectives and demonstrated commitment to provide high confidence, cost-effective enrichment capacity is an ingredient of this marketplace which our utility customers have a right to expect. The confidence and trust of our customers coupled with reasonable and competitive prices will restore the U.S. enrichment enterprise market share.

I believe the GCEP program and the earliest practical introduction of Set V centrifuges are key elements of a high confidence strategy. GCEP represents a significant investment to date. It is on cost and on schedule and the private sector industrial base is established. I think incremental expansion of centrifuge capacity is prudent provided that there is sufficient decision lead-time for each next increment. I think planning for at least four buildings of GCEP should proceed and the option for more not be precluded. I am not qualified to address the various alternate financing schemes under discussion, but recommend they be carefully considered and coordinated. All parties with a substantive role should be included in this activity: DOE, Congress, the utilities and the private sector. Each could make a valuable contribution.

I thank you for your attention and courtesy.

Mrs. Lloyd. Thank you very much, Dick, for your very fine statement. Dr. Hartig, we look forward to hearing from you now.

STATEMENT OF DR. E. O. HARTIG, VICE PRESIDENT, GOODYEAR AEROSPACE CORP., A SUBSIDIARY OF THE GOODYEAR TIRE & RUBBER CO.

Dr. Hartig. Thank you, Madam Chairman and members of this committee. I'm E. O. Hartig, vice president of the Goodyear Aerospace Corp. We also manufacture centrifuges for the Department of Energy's GCEP project, and we have participated in their development since 1972. We appreciate the opportunity to share with the committee our thoughts and concerns about uranium enrichment. Madam Chairman, in the interest of time, I'm going to summarize my written statement and request that the full text be included in the record.

Mrs. Lloyd. Without objection, your entire statement will be made a part of the record, and you may summarize as you wish.

Dr. Hartig. The U.S. uranium enrichment service is a $2-billion-a-year enterprise which operates without subsidy and over the years has contributed substantially to the U.S. trade balance. However, in recent years the United States has been losing market share to foreign competition. Regaining U.S. leadership will require strong, aggressive DOE management with decisions based on sound business principles free from political pressures.

The key to any business is the knowledge and sensitivity to the market. DOE's new contract offering is a good example of how the Department is being more responsive to the market needs.

The development and timely implementation of low-cost enrichment technologies are essential to long-range competitiveness. Most important, the business needs a continuity of plan and purpose. The on-again, off-again approaches of the past must end, and a "get on with it" attitude is needed to regain leadership and to assure industry that the United States is serious in its intent to continue as a reliable, low-cost producer of enriched uranium.

DOE's fiscal year 1985 enrichment budget request is constrained by its traditional policy of operating within annual revenues. Under this restriction, Goodyear agrees that the plan is a reasonable compromise between operations, research and development, and construction activities.

And while we appreciate DOE's desire to maintain a zero appropriations position, particularly in time of high Government deficits, this is not a cost-effective way for carrying out a modernization project such as GCEP, and it would not be the approach used by private business.

We also feel that it is important to point out that the original GCEP construction procurement program anticipated a requirement for an appropriation request over several years with payback by revenues in future years. With a modest amount of additional funding, centrifuge production rates could be maintained at their present levels rather than at the reduced level proposed by DOE, a level that would utilize only 25 percent of industry's dedicated centrifuge production capacity. Specifically, the higher fill rate would improve the production efficiency, decrease machine costs, and avoid the layoff of a substantial number of trained and security-cleared employees. This would eliminate the rehiring of qualified new people when production is increased on the set V machines.

We suggest that DOE study the cost-effectiveness of this approach. This would permit the early startup of process building No. 1, which has 80 percent of its piping and service modules and other support equipment already in place. The early production of separative work from this facility would provide an earlier return on taxpayers' investment with very little increased cost and without sacrificing already sunk investments. It would also allow industry an opportunity to recover a limited amount of their $185 million of private investment. We agree with DOE's plan to continue in fiscal year 1985 with development of advanced enrichment technologies.

We are a strong proponent of the advanced gas centrifuge and favor its rapid development and early deployment. Progress last year has confirmed our confidence and enthusiasm for this technology. AGC builds on a solid base of over 25 years of centrifuge development and operations. Basic theories and computer models have been verified in actual designs. The operating problems have been identified, solved, and full-scale systems are operating, and an industrial development team is in place. This is the only advanced enrichment technology with this history. The key to the advanced centrifuge is the development of the new high-speed rotor. Full-scale AGC rotors, manufactured on current production equipment, have been built by Goodyear and the other two centrifuge manufacturers. Performance tests on the rotors have met all our expectations. The work on gas dynamics has confirmed our approach is sound.

We are confident that the final performance and cost objectives can be met and, assuming proper funding, fully qualified—and I emphasize—fully qualified set V hardware can be ready for GCEP installation in December of 1988. Goodyear has agreed with DOE's support of the AVLIS process until its potential and real costs can be factually established. Recently DOE has concluded that budget and business constraints will not permit parallel full-scale demonstrations of both technologies; that is, AGC and AVLIS.

Therefore, in fiscal year 1985 they plan to select one of the technologies for full-scale development and a slowdown of the other. We support this plan and feel confident that sufficient data and test results will be available on the AGC process to proceed with confidence at that point.

In summary, then, one, based on DOE's zero appropriations constraint, we support the Department's enrichment plan as being a reasonable compromise between gaseous diffusion operations, research and development on new technologies, and GCEP construction. Second, the GCEP program is on schedule and within budgeted cost. The objective should be to complete the program as efficiently and as rapidly as possible. Three, we recommend that DOE maintain the current centrifuge production rate as a cost-effective means for filling process building No. 1. Fourth, we agree with DOE's plan to select one advanced enrichment technology for early implementation, based on prudent business risk. Five, we are confident that the AGC set V technology is sound, mature, and will be cost-effective. Six, we recommend that Congress and DOE plan and implement the minimum four-building GCEP complex.

An early decision should be made to add capacity as soon as DOE can confidently project its market base. Seven, future actions should be directed toward improving the U.S. competitive petition in the enrichment market. This is necessary to protect the taxpayers' investment, the costly privately funded investments, and the jobs of thousands of trained, skilled workers already working on the program in 41 States. Thank you, Madam Chairman, for giving me an opportunity to express Goodyear's views on the enrichment program.

[The prepared statement of Dr. Hartig follows:]

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STATEMENT
DR. E. O. HARTIG
VICE PRESIDENT, GOODYEAR AEROSPACE CORPORATION
SUBSIDIARY OF
THE GOODYEAR TIRE & RUBBER COMPANY
BEFORE
THE SUBCOMMITTEE ON ENERGY RESEARCH & PRODUCTION
U.S. HOUSE OF REPRESENTATIVES
FEBRUARY 28, 1984

MADAM CHAIRMAN, MEMBERS OF THE COMMITTEE, I AM DR. E. O. HARTIG, VICE PRESIDENT OF THE GOODYEAR AEROSPACE CORPORATION, A MANUFACTURER OF CENTRIFUGE ENRICHMENT EQUIPMENT FOR THE DEPARTMENT OF ENERGY.

THE PURPOSE OF MY STATEMENT IS TO STRONGLY SUPPORT THE CONTINUATION OF THE DEPARTMENT OF ENERGY'S PROGRAM FOR THE CONSTRUCTION OF THE GAS CENTRIFUGE ENRICHMENT PLANT, GCEP, AND TO ENCOURAGE BOTH CONGRESS AND DOE TO OPERATE THE U.S. ENRICHMENT ENTERPRISE IN AN AGGRESSIVE AND BUSINESS-ORIENTED WAY. TO OPERATE THE ENRICHMENT FACILITIES AS A BUSINESS REQUIRES CONTINUED ANALYSIS AND SENSITIVITY TO THE REQUIREMENTS OF THE MARKETPLACE AND COMPETITION. THE NEW CONTRACT OFFERING IS AN EXAMPLE OF HOW DOE IS BEING MORE RESPONSIVE TO THE CUSTOMER'S NEEDS. THE CONTINUED DEVELOPMENT OF THE NEW PROCESS TECHNOLOGIES IS NEEDED TO MAINTAIN A POSITION OF LEADERSHIP. A CONTINUITY OF PLAN AND PURPOSE AND A "GET ON WITH IT" ATTITUDE IS NEEDED TO ASSURE THE INDUSTRY THAT DOE WILL CONTINUE TO BE A RELIABLE, LOW-COST PRODUCER OF ENRICHED URANIUM.

I KNOW THAT THIS IS A DIFFICULT TASK COMPOUNDED BY THE ANNUAL FUNDING UNCERTAINTIES, BUT CONSISTENCY OF POLICY AND PURPOSE IS MANDATORY IF THE U.S. ENRICHMENT BUSINESS IS TO CONTINUE TO BE SUCCESSFUL AND GROW AND AGAIN BE THE RECOGNIZED LEADER IN THE WORLD MARKETPLACE.

WE ARE CONCERNED WITH THE PERCEIVED LACK OF CONTINUITY OF POLICY AND THE WIDE SWINGS OF PROGRAM OBJECTIVES THAT ARE DISRUPTIVE, COSTLY AND CONFUSING TO CENTRIFUGE MANUFACTURERS, THEIR EMPLOYEES, AND I'M SURE, DOE'S CUSTOMERS. WITH THIS BACKGROUND, I WOULD LIKE TO ADDRESS THE CONCERNS AND SPECIFIC PROBLEMS THAT WE FEEL NEED TO BE CONSIDERED BY YOUR COMMITTEE IN MAKING AUTHORIZATION JUDGMENTS FOR FISCAL 1985.

OVER THE PAST SEVERAL MONTHS NUMEROUS RUMORS AND "WHAT IF" SCENARIOS HAVE BEEN ADVANCED CONCERNING THE NEAR- AND LONG-TERM OPERATION OF DOE'S ENRICHMENT ENTERPRISE. THIS ON-AGAIN, OFF-AGAIN APPROACH WEAKENS OUR POSTURE WITH CUSTOMERS SINCE THEY PERCEIVE AN INCONSISTENCY OF PURPOSE.

WHILE WE APPRECIATE DOE'S DECISION TO MAINTAIN A ZERO APPROPRIATION POSITION, PARTICULARLY AT A TIME OF HIGH GOVERNMENT DEFICITS, WE FEEL IT IS IMPORTANT TO POINT OUT THAT THE ORIGINAL GCEP CONSTRUCTION/PROCUREMENT PROGRAM ANTICIPATED A REQUIREMENT FOR AN APPROPRIATION REQUEST OVER SEVERAL YEARS WITH PAYBACK BY REVENUES WITHIN A "REASONABLE PERIOD."

WE WOULD QUESTION THE BUSINESS JUDGMENT OF SLOWING THE INITIAL FILL RATE OF THE FIRST PROCESS BUILDING TO A PACE LESS THAN ORIGINALLY PLANNED.

WE WOULD ALSO QUESTION THE REASONING THAT WOULD LIMIT INSTALLATION OF THE CURRENT GENERATION CENTRIFUGES WHILE THE GCEP BUILDING AND BALANCE OF PLANT EQUIPMENT IS OVER 80 PERCENT COMPLETE AND READY FOR CENTRIFUGE INSTALLATION. THIS IS NOT A COST-EFFECTIVE OPERATING PLAN. A PRIVATE BUSINESS POSTURE WOULD NOT LIMIT EXPANSION TO FUNDING OUT OF REVENUES WHEN COMPETITIVE PRESSURES DICTATE IMMEDIATE ACTION. A MORE REALISTIC FINANCING POLICY SHOULD BE FOLLOWED.

SPECIFICALLY, THE HIGHER FILL RATE WOULD IMPROVE THE PRODUCTION EFFICIENCY OF THE CENTRIFUGE MANUFACTURERS, DECREASE MACHINE COSTS, AND AVOID THE LAYOFF OF SUBSTANTIAL NUMBERS OF TRAINED AND SECURITY CLEARED EMPLOYEES. THIS WOULD ELIMINATE THE REHIRING OF QUALIFIED NEW PEOPLE WHEN PRODUCTION IS INCREASED ON SET V MACHINES. THE CENTRIFUGE MANUFACTURING FACILITIES PROVIDED BY INDUSTRY WOULD BE UTILIZED AT A HIGHER RATE THAN THE 25 PERCENT OF CAPACITY PROJECTED. WE SUGGEST THAT AN ALTERNATE PLAN BE STUDIED BY DOE WHEREIN CURRENT PRODUCTION RATES ARE HELD. THE COST EFFECTIVENESS OF THIS APPROACH SHOULD BE STUDIED SINCE IT WOULD PERMIT THE EARLY PRODUCTION OF SEPARATIVE WORK FROM ONE FULL PROCESS BUILDING USING EQUIPMENT ALREADY INSTALLED AND PROBABLY INCREASE THE EARLY RETURN OF TAXPAYERS' INVESTMENTS AT VERY LITTLE INCREASED COST AND WITHOUT SCRAPPING ALREADY SUNK INVESTMENTS.

WE AGREE WITH DOE'S PLAN TO CONTINUE IN FY-85 THE DEVELOPMENT OF ADVANCED ENRICHMENT TECHNOLOGIES. THIS ALLOWS THE IMPLEMENTATION OF A SOUND BUSINESS PLAN TO SELECT A PROVEN AND ADVANCED ENRICHMENT PROCESS AS EARLY AS IS PRACTICAL WITH REASONABLE RISK.

LET ME BE SPECIFIC. WE ARE STRONG PROPONENTS OF THE ADVANCED GAS CENTRIFUGE DEVELOPMENT AND ITS RAPID DEPLOYMENT. WE ALSO AGREE THAT THE AVLIS TECHNOLOGY SHOULD BE PURSUED UNTIL ITS POTENTIAL AND REAL COSTS COULD BE DETERMINED FACTUALLY. WE STILL SUPPORT THIS POSITION BUT MUST REALISTICALLY AGREE THAT CURRENT BUDGETARY AND BUSINESS CONSTRAINTS MAY NOT PERMIT PARALLEL FULL-SCALE DEMONSTRATION OF TWO NEW TECHNOLOGIES. THEREFORE, WE SUPPORT THE POLICY OF AN EARLY CHOICE OF ONE TECHNOLOGY AND A SLOWDOWN OF A BACKUP PROCESS.

PROGRESS MADE IN THE LAST YEAR HAS CONFIRMED OUR CONFIDENCE AND ENTHUSIASM IN THE AGC APPROACH. AGC IS BASED ON A SOLID FOUNDATION OF OVER 25 YEARS OF CENTRIFUGE DEVELOPMENT AND OPERATION. THE BASIC CENTRIFUGE THEORIES HAVE BEEN TESTED IN ACTUAL DESIGNS AND THE OPERATIONAL PROBLEMS HAVE BEEN IDENTIFIED, SOLVED AND THE FULL-SCALE SYSTEMS ARE OPERATING. THIS IS THE ONLY ADVANCED TECHNOLOGY WITH THIS HISTORY.

KEY TO AGC IS DEVELOPMENT OF THE NEW ROTOR AND THE GAS DYNAMICS INVOLVED IN HIGH-SPEED OPERATIONS. WE HAVE BUILT AGC ROTORS WITH THE NEW MATERIALS EMPLOYING CURRENT PRODUCTION TOOLING AND HAVE EXPERIENCED NO PROBLEMS. PERFORMANCE TESTS ON THE ROTORS HAVE MET ALL OF OUR EXPECTATIONS. OUR WORK ON GAS DYNAMICS HAVE CONFIRMED THAT OUR APPROACH IS SOUND.

FULL-SCALE AGC MACHINES ARE IN OPERATION AND THE DEVELOPMENT OBJECTIVES ARE BEING MET ON SCHEDULE. THE PROGRAM IS BEING CARRIED OUT WITHIN PROJECT COSTS. WE ARE PLEASED WITH THE RESULTS OF PERFORMANCE TESTING TO DATE. WE ARE CONFIDENT THAT THE FINAL AGC DESIGN WILL MEET THE PERFORMANCE, COST AND SCHEDULE OBJECTIVES.

WE DON'T DISAGREE WITH AVLIS PROPONENTS' PREDICTIONS OF THEIR EVENTUAL SUCCESS. HOWEVER, THEIR ECONOMIC PROJECTIONS NEED MORE VALIDATION. WE SAY WALK BEFORE YOU RUN AND BEFORE YOU COMMIT YOUR FUTURE TO PROCESS DECISIONS NOT YET ADEQUATELY TESTED.

IN SUMMARY,

- WE SUPPORT THE BASIC DOE ENRICHMENT BUSINESS PLANS. THE GCEP PROGRAM IS ON SCHEDULE AND WITHIN BUDGETED COST. THE FORWARD POLICY SHOULD BE TO COMPLETE THE PROGRAM AS EFFICIENTLY AND RAPIDLY AS POSSIBLE.

- WE FEEL THAT DOE SHOULD MAINTAIN THE CURRENT CENTRIFUGE PRODUCTION BASE AS A COST-EFFECTIVE MEANS FOR THE EARLY FILLING OF PROCESS BUILDING NO. 1. THIS IS NECESSARY TO START THE REDUCTION OF ENRICHMENT COSTS. FIND OFF BUDGET FUNDS TO ACCOMPLISH THIS IF NECESSARY.

- WE AGREE WITH DOE SELECTING ONE ADVANCED TECHNOLOGY AND IMPLEMENTING IT AS RAPIDLY AS POSSIBLE BASED ON MINIMUM BUSINESS RISK.

- WE BELIEVE THAT THE ADVANCED GAS CENTRIFUGE TECHNOLOGY IS SOUND, MATURE AND WILL BE COST-EFFECTIVE.

- WE BELIEVE THAT DOE SHOULD EXPEDITE THE AGC DEVELOPMENT UTILIZING THE STRONG INDUSTRIAL DEVELOPMENTAL CAPABILITY NOW IN PLACE. DOE SHOULD SCHEDULE EARLY PRODUCTION OF THE AGC CENTRIFUGE FOR INSTALLATION IN PROCESS BUILDING NO. 2 AND SUBSEQUENT BUILDINGS.

- WE ENDORSE THE POLICY THAT CONGRESS AND DOE SHOULD PLAN AND IMPLEMENT A MINIMUM FOUR BUILDING GCEP PLANT. AN EARLY DECISION SHOULD BE MADE TO ADD GCEP CAPACITY AS SOON AS DOE CAN CONFIDENTLY PROJECT ITS MARKET SHARE AND PRODUCTION BASE.

- FUTURE ACTIONS SHOULD BE TAKEN TO IMPROVE THE U.S. COMPETITIVE POSITION IN THE ENRICHMENT MARKET. THIS WILL NECESSITATE PROTECTING BOTH THE TAXPAYERS' PROJECT INVESTMENT AND THE COSTLY PRIVATELY FUNDED INVESTMENTS ALREADY IN PLACE AND THE JOBS OF THOUSANDS OF TRAINED, SKILLED WORKERS ALREADY WORKING ON THE PROGRAM IN 41 STATES.

THANK YOU, MADAM CHAIRMAN, FOR GIVING ME AN OPPORTUNITY TO EXPRESS GOODYEAR'S VIEWS ON THE ENRICHMENT PROGRAM.

Mrs. LLOYD. Well, thank you very much, Dr. Hartig. All three of you have given very excellent statements, and we appreciate the time and preparation of your remarks. The questions I have for the three of you can be answered by any of you, so you can feel free to speak up as you wish, rather than me directing a question to just one of you.

I think when you talk about the economics of the set III machines, do any of you agree that either the two- or the four-building GCEP set III technology is uneconomic?

Mr. ROWAN. Do we agree that it is uneconomic?

Mrs. LLOYD. Yes.

Mr. ROWAN. No, I wouldn't say that with respect to process building 1, in particular, Mrs. Lloyd. All three of us in different modes have developed a theme with you of the economic value of continuing with the production base of centrifuge at the current level, enough to finish up process building 1. We do thoroughly agree that the potential is so great in set V that that should be earmarked for building 2 and for retrofit of building 1, as well as the additional process building increments 3 and 4. It's the matter of avoiding production interrupt, I guess, that we're dealing with there. That has a value, a great value.

Mrs. LLOYD. I grant the fact that all of you have suggested that we move ahead in this direction, but that's not the point that I was making. I was talking about the economics. Dick, would you like to address that?

Mr. GRANT. Let me, first of all, say that economics, of course, are in the eyes of the beholder. If you start out to build something in a certain quantity and justify its economics on that basis, and then decide that what you're going to do is force the whole front-end cost of the program against the first five centrifuges you put in, it's obviously uneconomic. Let me say, though, that from the standpoint of the operation, operating costs, replacement equipment costs, personnel costs, the plant, and recovering the capital but not necessarily interest, because I don't have any way to play that game the way economists do, it is economic in a two-building GCEP. If all you did was consider the operating costs of even a much smaller increment, it's also economic. The point is that a two- or four-building GCEP, when those costs are calculated, you bet its economic. The cost of power, the cost of people, the cost of replacement equipment lumped together is economic.

Mrs. LLOYD. How much do you estimate the dollars per SWU in this scenario?

Mr. GRANT. In terms of the operating costs that I just described—the operating personnel, replacement equipment, electricity, and other utilities—about $35.

Mrs. LLOYD. OK. Well, the information that I had received, Dick, states that the overall cost runs around $200 a SWU.

Mr. GRANT. I submit that that must contain front-end costs for costs that were incurred that had nothing to do with the two-building GCEP. As an example, the recycle assembly building that's sitting out there today, a terribly costly device, was designed for eight buildings of GCEP. But its costs were incurred in very large measure because it was designed for eight buildings of GCEP. And I'll stipulate that if you insist on ascribing that to the cost of a two-building GCEP, you bet it's uneconomic.

Mrs. **Lloyd**. Dr. Hartig?

Dr. **Hartig**. I think you have to consider the cost that would be involved in shutting down three manufacturers, and perhaps at some later time reestablish a business base. There is equipment in place; there is depreciation on that equipment. That equipment is being depreciated. And those are the largest costs involved in manufacturing centrifuges. It's that huge capital equipment that's being depreciated. That depreciation has to come sometime. Whether it comes now or later, you're going to have to pay for it. You're going to have to pay for retraining people. Those are the costs that you have to consider. Those are the real costs.

Mr. **Rowan**. I think that was the point I was trying to make, too, Madam Chairman. It's the cost of interruption that's tremendous.

Mr. **Grant**. Could I suggest one other point, please?

Mrs. **Lloyd**. Certainly.

Mr. **Grant**. In the various calculations that include the cost of interest on capital—it might be interesting to recall that one of the things prohibited by contracting with the Department of Energy on our part is, in fact, the recovery of interest on our capital.

Mrs. **Lloyd**. Thank you. Dr. Hartig? Anything further?

Dr. **Hartig**. No.

Mrs. **Lloyd**. Thank you. You related, all of you in your testimony, to the techniques in set III production that were applicable to set V. Would you like to elaborate further?

Mr. **Rowan**. It's a little difficult to do because of some of the classified aspects of it that would——

Mrs. **Lloyd**. That's what I was wondering, is this classified?

Mr. **Rowan**. No, I understand. I'm saying many of the goodness features that we'd like to be able to tell you about are resident in that sector. But in our case—and I think probably we need to have both Boeing and Goodyear speak to that point themselves—but I think it would be true for all three of us that the rotor fabrication techniques, that what we're talking about, Madam Chairman—all three of us had thought that they would be more difficult than they were, and we are discovering that, with very little change, the processes that we are all using, and quite successfully, on the set III rotor are applicable to set V. That's what we had reference to. And in many of the other pieces of process technology, too, in the program—it's a small-scale change on it in other subassemblies other than the rotor—upper suspension column, et cetera.

Mr. **Grant**. I might just say, as I mentioned in my talk, I've not bought one new piece of manufacturing equipment nor hired any special new individual for the fabrication of set V components, every one of which, to the best of my knowledge, is in fabrication in my factory in very small developmental quantities at this point.

Mrs. **Lloyd**. Very fine. Dr. Hartig?

Dr. **Hartig**. Just echoing the same thing, let me emphasize in round numbers that half of the cost of a machine is in the rotor, and these rotors can—these new rotors can be fabricated on the same equipment, and we have all used the same equipment for fabricating rotors, and we feel that it will be completely interchangeable. Other parts that may change are, more or less, standard, numerically controlled machines that can be reprogramed for whatever changes are involved. So I don't anticipate significant changes in either the tooling or the equipment used to build it.

Mrs. LLOYD. Let's go back to our cost of GCEP SWU's in the scenario using set V technology in a two- or four-building GCEP. Now would you include in this the cost of the initial set III machines, or how would you really estimate your cost?

Mr. GRANT. You're talking about an entire enterprise cost?

Mrs. LLOYD. Correct.

Mr. GRANT. Obviously, to the extent that we build set III machines, it becomes part of the enrichment enterprise. Those machines, although we tend to treat them as if they were stepchildren somehow or another of the program at this point, are nonetheless marvelous productive machines that produce—I've forgotten whether the number is classified or not, so I won't say it, but you know what the numbers are per machine per year. They sit there and do that year in and year out, and thereby become part of the enrichment enterprise. The CPDF facility in Oak Ridge has done the same thing with machines of the current set III design. The program that most of us visualize, I think—and I certainly won't try to speak for the other two—is a program that contracts and plans for "*x*" number of buildings. We suggest four. We think that that contracting can proceed just as if it was independent of whether it were a set III or a set V machine. The way you plan this thing, then, to transition set V's in is you get the set III production rate going, transition to set V's as they are ready for that transition, and then the set III's will be changed out as appropriate, as they would come off line in normal circumstances. Set III's are part of the enterprise and they are producing salable, separative work in the marketplace.

Mrs. LLOYD. Would you estimate the cost on this, on the SWU's——

Mr. GRANT. Oh, yes——

Mrs. LLOYD [continuing]. If we get in place four buildings or two buildings of set V's?

Mr. GRANT. Well, the ground rules get messy under these circumstances. If it would be appropriate, I'd be happy to supply to you, within a week, my assessment of the cost with different assumptions as to what the ground rules are for how you cost uranium enrichment for a two- and a four-building GCEP.

Mrs. LLOYD. If you would submit that to us, we will include it in the record.

Mr. GRANT. Of course.

[See response to questions in appendix.]

Mrs. LLOYD. Dr. Hartig?

Dr. HARTIG. We haven't made an analysis on the one-building complex. There are so many scenarios floating around, it's hard to analyze all of them. But we have made an analysis on the two-building set III complex, and we've supplied it to DOE, and they've used it in certain of their discussions.

For a two-building complex, set III, we came up with a number of, I believe, $85 to $87, SWU, incremental cost.

Mrs. LLOYD. $85 to $87. That would be without the sunk-cost?

Dr. **Hartig**. Without the—pardon?

Mrs. **Lloyd**. Without the capital costs included?

Dr. **Hartig**. Well, that's incremental cost. It does not include the sunk-costs.

Mrs. **Lloyd**. Thank you. What do you feel is the optimum purchase level for set III machines? How far should we go with this?

Mr. **Rowan**. Well, I think maybe in the case of Garrett, just from our point of view on it on that matter, Mrs. Lloyd, I think we should be continuing on at the current level and sufficient to complete the process of building one. That would probably be the best way to go about it; and that presumes putting into place the same kind of planning element that Dick referred to in his testimony, where you have sufficient leadtime given to you to make—to effect the transition on an orderly basis to the new model. But certainly, being able to continue on at the present production rates would be the most efficient production mode.

Mr. **Grant**. My response to that—oh, I'm sorry.

Mrs. **Lloyd**. What is the present number? Could you respond to that, Dick?

Mr. **Grant**. Thirty-five to forty a month.

Mrs. **Lloyd**. Thirty five——

Dr. **Hartig**. Per each contractor. It's in that range; if you multiply either one of those numbers by three, you're in the right ball park. It varies from month to month a little bit, and it varies with components. My scenario is slightly different, perhaps, in that what I've tried to suggest is that we produce at this level and continue to produce at this level until the set V is ready and transition it into that production program in an orderly way so you don't disrupt production.

Mrs. **Lloyd**. I think DOE is scheduled to go to about 25 per vendor per month; isn't that correct? In the 1985 budget?

Mr. **Grant**. I think that that was the kind of number that was alluded to at various times. I think, though, they are less—I don't mean to speak for them, but my current discussions with them indicate they're less tied to 25 machines than they are to say, "this is what we're trying to live within from a budget standpoint."

Mrs. **Lloyd**. But if you go to this level, now, would this minimize your unit cost and let you cut down your personnel?

Mr. **Grant**. No. If we go to that level we'll lose personnel and the unit cost, by my estimate, will go to about 1.2 times what it is now, or a 20- percent increase per unit.

Mr. **Rowan**. That's essentially what our data indicates too, Mrs. Lloyd.

Mrs. **Lloyd**. You feel that this purchase level of DOE is inadequate?

Mr. **Grant**. If it were stipulated at, say, 25 or something like that, yes.

Mrs. **Lloyd**. Well, I think that the real concern of this committee is that if centrifuge technology becomes too expensive, then it raises the possibility of it being dropped in future years in favor of AVLIS technology; so this is the real concern, I think, you know, of this committee. Would you care to respond to that?

Mr. **Grant**. Once again, I contend that whether or not it's too expensive depends on the ground rules for the arithmetic.

Mrs. **Lloyd**. As you know, there are 435 Members of this body that pass judgments on it.

Mr. **Grant**. Yes; we need some fairly solid rules on the arithmetic that everyone plays by those rules, and that, in fact, it can be justified in terms of the way people have to do business. I cited earlier the interest on capital, for instance, where we as a contractor are prohibited from charging interest on our capital; but then calculations for purposes of making future projections on the cost of enrichment include the interest on capital. It's a different kind of a circumstance, in my view.

Mrs. **Lloyd**. Dr. Hartig?

Dr. **Hartig**. Well, our feeling is, and from past experience, that many technologies in the early stages look very promising and the known processes and technologies can be estimated very accurately; and I think you have to take that consideration into account.

Mrs. **Lloyd**. You made that point well in your statement.

Would any of you here—I don't think you'll like this question—would any of you here favor a narrowing of the competition to two vendors? Dividing the funding between two vendors?

Mr. **Rowan**. I honestly think that that would be to the Government's disadvantage, Mrs. Lloyd, I really do. Narrowing to two vendors is tantamount, in my view, to prejudging the outcome on AVLIS versus centrifuge, for one thing. And second, it leads to a kind of a deal, a too-early-on kind of situation here that's characterized by primarily a lead vendor-supplier on centrifuges and a support vendor. It couldn't be otherwise, really. And so what has the Government then done to prepare itself for a competition on set V AGC when and if the requirements ramp up here for SWU in a modernized plant? In other words, you'd be predeciding the issue by making that decision today, long before the time has come to do that.

Mrs. **Lloyd**. I think the general agreement is no.

Mr. **Grant**. I'll probably say the same thing, but maybe I'll say it slightly differently. In the past it's always been my view that if we intended to come down to two, from three, that there was no great favor being done to myself, certainly—if I was to be the loser, let's say—by stringing me along and allowing me to spend more money on the process. But the situation of the competition introduces a new element, however; you may not be aware that the DOE has proceeded over the years to split up the R&D work among the three of us, therefore apportioning some here, some here, some here. And so that now when you suddenly decide that you want to have a competition for the whole thing, you say, "well, we get rid of this guy," and he takes a key element of the development out of the picture—then that probably won't work.

Mrs. **Lloyd**. That point is well taken.

Dr. Hartig?

Dr. **Hartig**. The basis for making a selection between the two out of three would be very difficult at this time. The original plan was to move into phase II production where there'd be large-volume production and the program would go into a fixed price basis, based on competitive bids on this production; then the selection would be more logical. I think DOE would find it difficult to make a selection at this time. Perhaps they could.

Mrs. **Lloyd**. I think you're going to like this question better. [General laughter.] Could you productively use more money for advanced machine production?

Dr. **Hartig**. I think we could.

Mrs. **Lloyd**. And if so, would this translate into——

Mr. **Grant**. Well, I think when we're talking about making this technology decision in the early second quarter of 1985 that we're dealing with such short-term kinds of things that it's a tough one to answer. I think that at least in terms of what it would add to the demonstrations, we can certainly do a better job of those demonstrations; but I think you'd find that the amount of money that we would be talking about would be very modest. I certainly don't intend to speak for the other two gentlemen, but it's probably in the range of—$5 million to $10 million. It's not a lot of money that could productively be used to arrive at that point with something much more dramatic than we would otherwise.

Mr. **Rowan**. I think the answer has to be yes, obviously, Mrs. Lloyd, and it would be about in that range. I would estimate for all the participants in the program something on the order of $10 million, and what would it do is——

Mrs. **Lloyd**. Is that for each vendor?

Mr. **Rowan**. No, no. I think we're talking about program total there. And the main thing, of course, as Dick indicated there, with such an early decision date being proposed on it, in all cases it would be much better to have a greater range and depth of testing accomplished for the tangible results that would come from such efforts.

Mrs. **Lloyd**. Would you all favor a later decision date, perhaps 1987?

Mr. **Rowan**. No, I don't think so. I don't think so. I think there'll be sufficient information available in 1985 to do that.

Mrs. **Lloyd**. Do you agree?

Mr. **Grant**. Yes, we'll have full demonstrations producing SWU's.

Dr. **Hartig**. I think our company would like to see the decision made and get on with it or get off with it, one or the other.

Mrs. **Lloyd**. All of you agree that you prefer the 1985 decision date, then?

Mr. **Rowan**. Yes.

Dr. **Hartig**. Yes.

Mr. **Grant**. Yes.

Mrs. **Lloyd**. Thank you very much for your testimony. I would remind you, I hope that you will agree to submit to questions in writing for the record since some of our members obviously aren't here today.

We're most happy to welcome the ranking minority member of our subcommittee who does such a valuable job on the committee, Congressman Walker.

Mr. **Walker**. Thank you, Madam Chairman.

Madam Chairman, I do have an opening statement here that I would appreciate having put in the record——

Mrs. **Lloyd**. We have already agreed to put it in the record.

Mr. **Walker**. Very good. Thank you, Madam Chairman.

A couple of questions. Did the new proposed DOE uranium enrichment service contract attract sufficient attention to warrant additional GCEP project activity?

Mr. GRANT. Well, good question. I guess that since I tend to think that there will always be a market of some size for enriched uranium, and since my private sector background sort of suggests you probably ought to do that about as cheaply as you can, and since, third, I'm pretty sure that even if it didn't turn out that the contract response was very good that a day is coming when you have to do a good job for your utility customers—I think what DOE has to do at that point is make some tough decision as far as gaseous diffusion plants are concerned. They have to make some tough decisions as to what the new low-cost technology is and when they can put it on line within the framework of that revenue picture, and at the same time taking a hard look at how they put that marketplace that is available out into a different place of business.

Mr. WALKER. Dr. Hartig?

Dr. HARTIG. Well, I think that the first thing we'd do in a situation like that is go out in the market and find out the reasons why the utilities didn't respond and we'd try to correct those reasons. I guess that would be the first thing we'd do. Beyond that, I don't really—I haven't really thought the problem through. I don't really have any further comments.

Mr. WALKER. Mr. Rowan?

Mr. ROWAN. My answer to that, Congressman Walker, would be that I don't think that's going to happen, that is, an adverse response to DOG's new contract. I think it's a very proper question and a probing one, to postulate—I'm more sanguine about the Department of Energy's awareness of the depth of the problem that exists in the enrichment enterprise and their effort to do something about it. I think that the U.S. contract that's out now has, so far, shown a fairly good response and the votes aren't all in on it. I guess I remain optimistic that they're going to do much better with that contract than they have in the past; and that being so, for the sake of discussion here, I think that extreme measures will not be necessary. I do share E.O.'s view and Dick's view, though, that should something that dire happen, then dire measures in turn would then be required. And those would consist of some more radical plan, if you will, for a turn-down on the diffusion plants. You see, it's like a self-fulfilling prophecy. If we don't take the measures in the country now to anticipate the future in terms of plant modernization, then surely plant obsolescence is going to bite us. It has already, and it's going to continue to do so; it can only get worse. So we would tend to favor a plan that called for a right smart marketing approach. I think that the DOE is moving in that direction, combined with an aggressive plant modernization program.

Mr. WALKER. Well, I guess my question stems from the fact that there is some question about just what the market is for enriched uranium, and so I guess my follow-on question is, Do you see some need for a comprehensive market study?

Mr. ROWAN. Well, I think there is a continuing need for a market study going on. From all that I have been made aware of of what the DOE is doing in that area, they're applying intensive efforts on that right now.

I think there's a danger here of maybe overhelping the Department of Energy. They're so much on the spot. There have been so many problems connected with the enrichment enterprise. I personally feel that their management is keenly aware, acutely conscious of the problem, Congressman Walker, and that they have a program in place to deal with those marketing issues. I see much evidence of that, and particularly in the last year. Beyond that I can't say anything more. I think that if they are overhelped on it, with an array of outside help, that isn't really of a constructive nature; not that that would necessarily occur, but if it would occur then I think that they're going to be compromised in reaching their goal rather than getting there in a big hurry.

Mr. WALKER. As businessmen, do you feel comfortable with the kind of marketing approach and the kind of market studies that you see DOE proceeding with, or are you uncomfortable with the fact that sometimes Government tends to be very bad at evaluating markets and determining market strategies?

Mr. ROWAN. Well, I'm greatly encouraged, as I've said, by what I've seen the Department of Energy doing in the last year. I see a very concentrated effort on their part to deal with marketing issues; I really do.

Mr. WALKER. And you feel as if they're taking a businesslike approach to it?

Mr. ROWAN. I think it's greatly improving, I do. I think that the problem that I have on it, or maybe all of us would have—and our views would not necessarily be the same as the Department of Energy is, where they have to balance out risks from their point of view on the economic viability of existing diffusion plants, the rate at which they bring on the centrifuge plant, and what they do in long-term technology development contingency-planning in terms of AGC and AVLIS, and balancing all those out. From our point of view, I think we would be moving—want to move a little faster than they are on it.

Mr. WALKER. Well, I guess what concerns me is that I'm wondering whether DOE is proceeding with a strategy that would be acceptable to most businessmen. You know, I wonder, as businessmen, whether or not you would be willing to proceed with a multibillion-dollar production facility without any real handle on what the market for the product is going to be and without a target for a share of that market that you think that you can realistically capture? I mean, businessmen wouldn't operate that way.

Mr. ROWAN. No, of course not, nor would we; nor would we agree that the Department of Energy is unaware of the problem that you're describing. Again, Congressman, it gets back to the balance that would have to exist in the enterprise, depending whether it's Government or private industry.

Let me turn it around another way, if I might. I think if it were private industry we wouldn't be attempting to keep in service three diffusion plants with 7,500 employees operating at, maybe, half capacity. At the same time, try to bring on a plant modernization program in terms of, for example, GCEP. At the same time, that we would be aggressively pursuing in an intentionally competitive mode the introduction of an even more advanced technology, even earlier in the game, to wit: AVLIS. These aren't things that private industry would do. We would not put the pieces in place in that manner on this thing. There's a difference in approach.

But again, we're not the private entrepreneurs of the enrichment enterprise; the Government has all these other factors to consider. We've made our recommendations—I certainly have—and I think that the other two manufacturers have expressed similar views today, that basically there ought to be a more rapid turndown of diffusion; the plant modernization program should proceed at a controlled pace; and an artifical, or contrived, competition—technological competition—between the two, AVLIS and advanced centrifuge, should not be part of any carefully constructed business scheme.

Mr. GRANT. Slightly differently, perhaps, it's my opinion as a businessman and otherwise that it's an awfully long time before there's zero market for enriched uranium; many, many years. And under those circumstances it takes on a little different kind of character as far as betting on the future is concerned. If you were betting on a future that included zero as an option, then I think you'd be in a very different situation. Clearly, you wouldn't build anything new to the extent that you evaluated the risk of zero as being nonzero.

The point of it is that in that sense, then, it becomes very much like the decision to build two new airplanes, the 757 and a 767, 30 percent-plus more fuel efficient at a time when fuel prices were high. The world turned around; fuel prices came down a little bit or stayed the same, as the case may be, but you can be very sure that we haven't suddenly decided that those two new airplanes were a bad idea. They weren't; they were an excellent idea, and for all the same reasons they were a good idea when the price of fuel was high and going higher every day, because that'll happen again. And even if it doesn't, saving 30 percent of your cost of fuel is a good idea just as using 5 percent as much electricity is a good idea, in this case.

Mr. WALKER. Yes. Well, if I can follow up on your analogy, though, to some extent the decision to build that new class of airplanes is based upon the fact that they can project an expanding aircraft market. In other words, there very definitely are going to be more and more people traveling by air; I mean, the new planes coming online are in partial response to that. Part of my question stems from the fact that I'm not certain that we have market studies to show that that's the case in enriched uranium. We may, but I've lost sight of where we see those kinds of——

Mr. ROWAN. Congressman Walker, I think the United States can really create the market by lowering the price because everything comes down to economics; and if nuclear power is lower in cost than any other means of generating electric power, then the nuclear facilities throughout the world will increase. Already in Europe, Japan, the Far East, why, there's an expansion of nuclear, and in the United States it's slowing down. The only viable competitor to nuclear in the world today is coal and that has many problems, too. And if nuclear power becomes much less costly, that'll have a big impact.

Mr. **Walker**. OK, let me ask one other business-oriented question here, then. What money could be saved on each set III machine if they were purchased on a competitive, fixed-cost basis?

Dr. **Hartig**. Depends on the quantity. You know, that's a difficult question to answer.

Mr. **Grant**. Well, not that we're trying to insult your intelligence, but clearly it is very different if you bought 10 or 10,000. But basically, what fixed-price contracting does for the Government, of course, is to give it a value-certain, a price-certain as a basis for contracting. And, of course, it gives you a different kind of formula for controling profits. Remember that DOE has profit guidelines on a cost-plus contract and on a fixed-price contract within which they insist on you living. So I think if you—first of all, remember that the price for 10,000 centrifuges, for example, of the set III variety, taken from where we're at today, is about—let me get the number right here—about 42 percent of what the cost today is, I guess.

Mr. **Walker**. OK. Well, let me give you a figure that we're shooting for in savings here. What if we filled buildings 1 and 2 at Portsmouth on one contract? What kind of difference in cost are we talking about?

Mr. **Rowan**. On one contract? You mean one supplier?

Mr. **Walker**. One supplier.

Mr. **Grant**. Well, I haven't looked at that one. It would take a little while, but we could probably give you an answer on it.

Mr. **Walker**. Well, you know, if you could give us an answer in writing, that would be most helpful.

Mr. **Grant**. All right, fine. We'll do that.

Mr. **Walker**. Thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much, Mr. Walker, and we thank you witnesses for your very valuable testimony. You've done a fine job this morning.

Our next panel includes Dr. John L. Emmett, who is associate director of Lawrence Livermore National Laboratory; Mr. William McWhorter, who is project manager, advanced gas centrifuge program, Union Carbide Corp.; and Mr. George Rifakes, vice president, Commonwealth Edison Co., representing EEI.

Excuse me, I think Mr. Rifakes is separate. Pardon me. Mr. McWhorter and Dr. Emmett, we welcome you and you may proceed with your testimony.

STATEMENT OF DR. JOHN L. EMMETT, ASSOCIATE DIRECTOR, LAWRENCE LIVERMORE NATIONAL LABORATORY

Dr. **Emmett**. Madam Chairman, members of the committee, it's a pleasure to be here today and talk to you about the uranium enrichment business. I would like to second what my illustrious colleagues have said earlier, that we're pleased with the fact that DOE is fundamentally addressing the problems that have arisen in the enrichment business and have caused so much concern to us all. We are in basic support of the plan that they have proposed for an early process selection between the AGC program and AVLIS. What I would like to do today is to outline for you what that early selection will mean in terms of what's available for AVLIS and what information is available; also, I'd like to make some commentary on this elusive matter of economics and cost.

I have a written statement that I would like to submit for the record, and then my verbal statement will be a shortened version of that in essence of time, if that's all right.

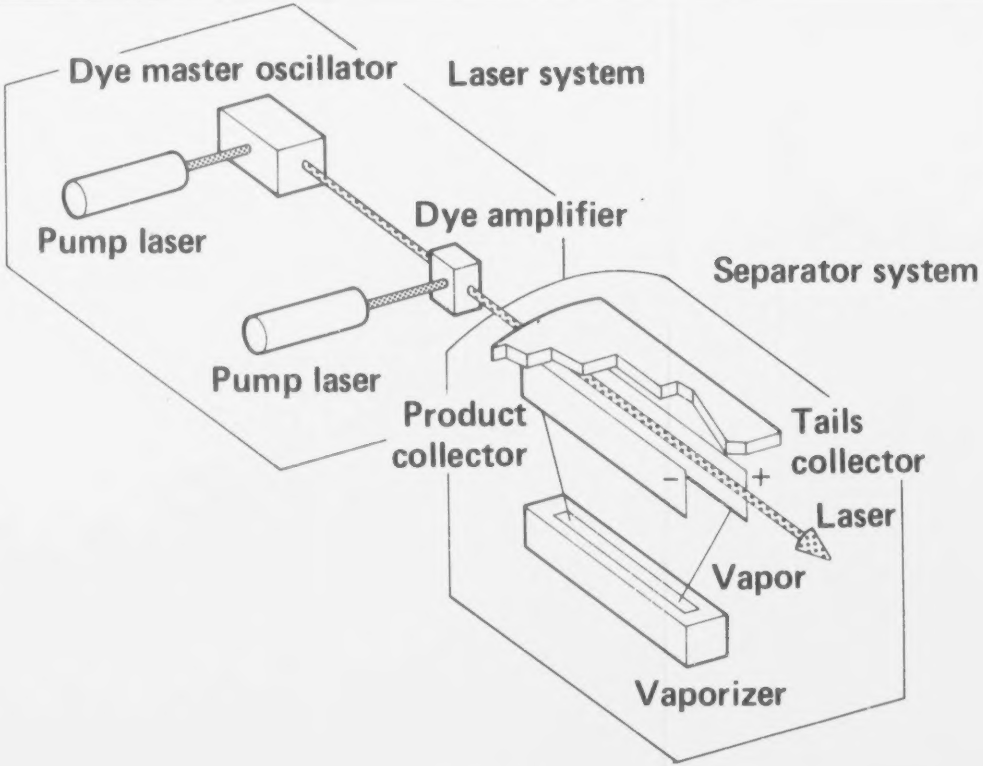
Mr. **Walker**. Without objection, your written statement will be made a part of the record.

Dr. **Emmett**. If it's all right with you, I would like to speak from the vu-graph machine.

I would just like to start off by reminding you of what the AVLIS concept is. (Viewgraph 1.) It's basically a system which vaporizes uranium. The uranium vapor flows up between collector plates, and laser beams come in between those collector plates and selectively ionize uranium-235, which is drawn over to the collector plates and extracted as a liquid flow.

One of the points that I would like to make to you today is that AVLIS enriches uranium. (Viewgraph 2.) We have run literally hundreds of enrichment runs on both uranium and plutonium. There is no question that the process enriches uranium. The only really remaining issue is the issue of cost, and I want to come back to that later toward the end of my statement.

Atomic vapor laser isotope separation – major systems


Dye master oscillator
Laser system
Pump laser
Dye amplifier
Separator system
Pump laser
Product collector
Tails collector
–
+
Laser
Vapor
Vaporizer

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Viewgraph 1

9/83

AVLIS development status — enrichment performance

- Single cell separative work performance has been validated in a series of integrated mass balance demonstrations

- A series of multicell tests have shown that single cell performance can be maintained in large multicell arrays

AVLIS process selection options

Selection Year	Demonstration Status	Cost FY84 Through Selection*
FY85	— Sub-scale systems Lasers — 20 %; separator — single cell — Operation duration ~10 hours enrichment; 100 hours collector — Limited economic data	$180M
FY86	— Full-scale systems Lasers — 100 %; separator — full multicell — Limited operation — Extensive economic data	$270M
FY87	— Full-scale systems — Full plant cycle operation — Conclusive economic demonstration	$400M

*Production plant activities limited to conceptual design and cost analysis.

70-01-0284-0500

Viewgraph 3

We have done these enrichment runs on what we call a single-cell separator, and we have also run multiple-cell collectors to demonstrate that there is no interaction between the cells. More details than that, I think transgresses classification.

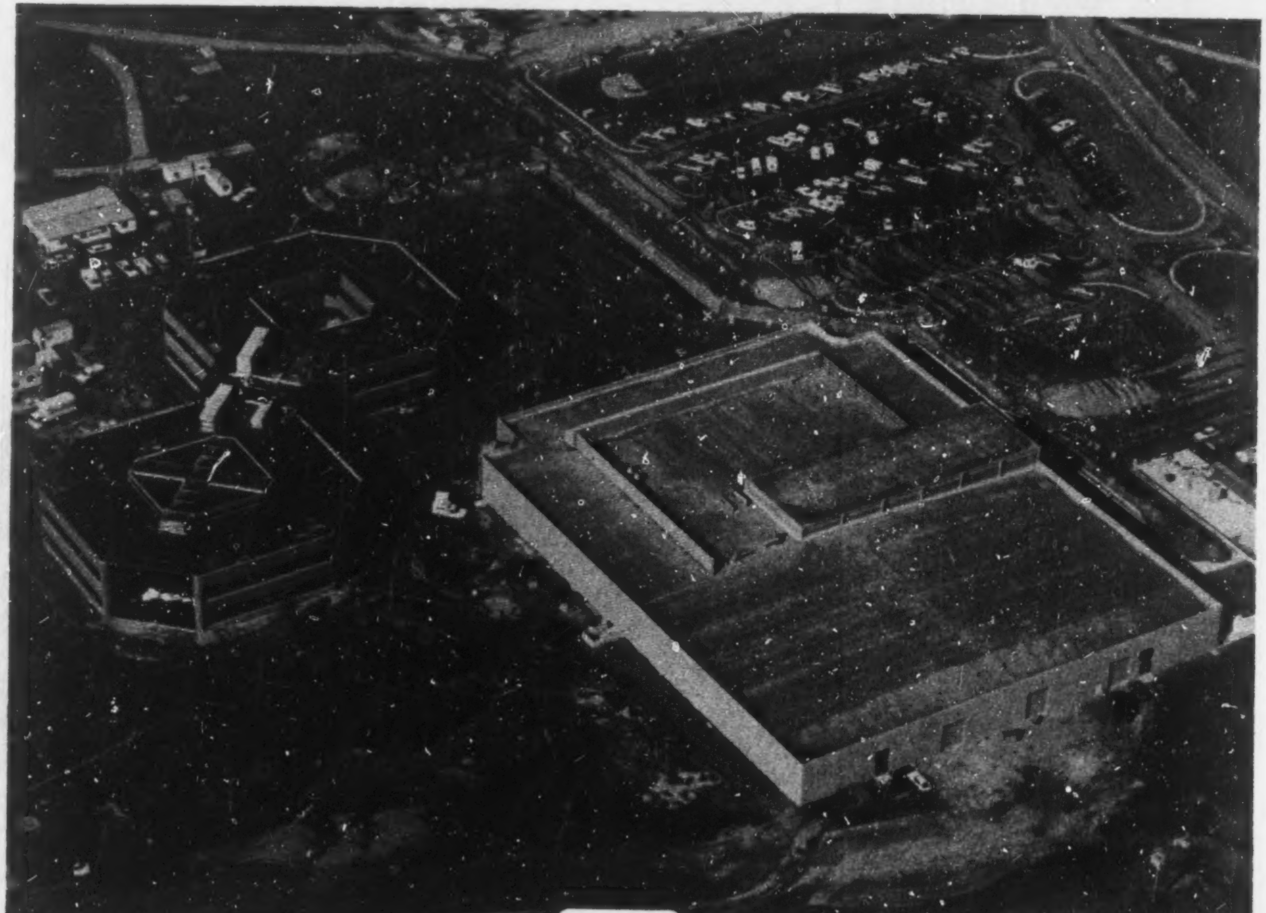
Now, let me address what the early selection that DOE proposes—what impact that has on the information that would be available. (Viewgraph 3.) First of all, if we do a selection in 1987, as we originally proposed in the program and DOE originally proposed, we would have full production scale systems, lasers, and separators. We would run full-plant cycle operations which are typically 200–400 hour cyclical runs, and we would have a conclusive economic demonstration because we would have all of the receipts from all of the equipment purchased and a direct measure of the separative work coming out of the hardware, and we would be running the hardware over intervals that are long compared to maintenance schedules.

Now, what we would have available in 1985 is that the lasers would be at 20 percent of production scale, and the separator would be a single cell, not a complete multicell array. And we would operate that for like 10 hours, which is like one-twentieth to one-fortieth of a full cycle production run. And we would run the multicell collectors like 100 hours, which is a quarter of a production run. The total integrated cost of that program in 1984 and in 1985 is $180 million, and is the one currently budgeted by the Department of Energy.

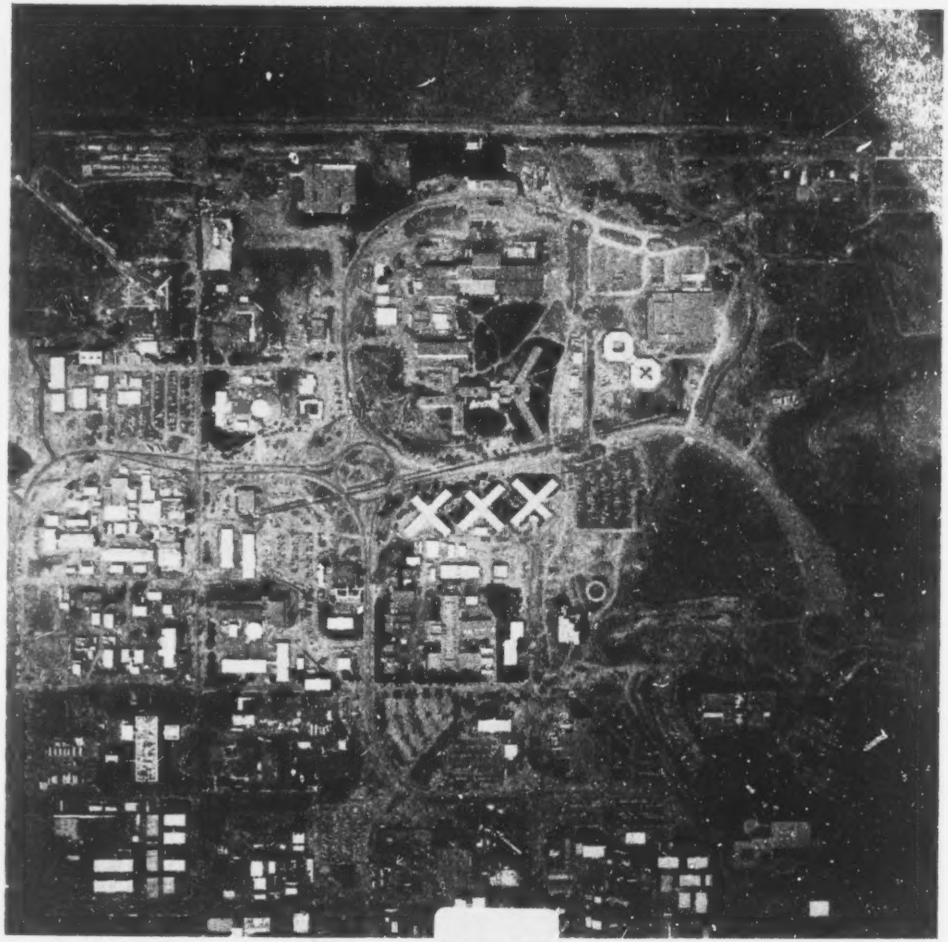
We were also asked to address what could be done if the decision were delayed until 1986. Basically, we would have the full scale systems, lasers, and separators, 100 percent of the laser system, the full multicell separators; by the end of 1986 we would probably only have a few full production cycles run rather than scores of production cycles. We would have extensive economic data, but not complete lifetime evaluation of all of the costs.

That is the program, and it's about $100 million more, about 1 more year of operation as a full-scale demonstration effort.

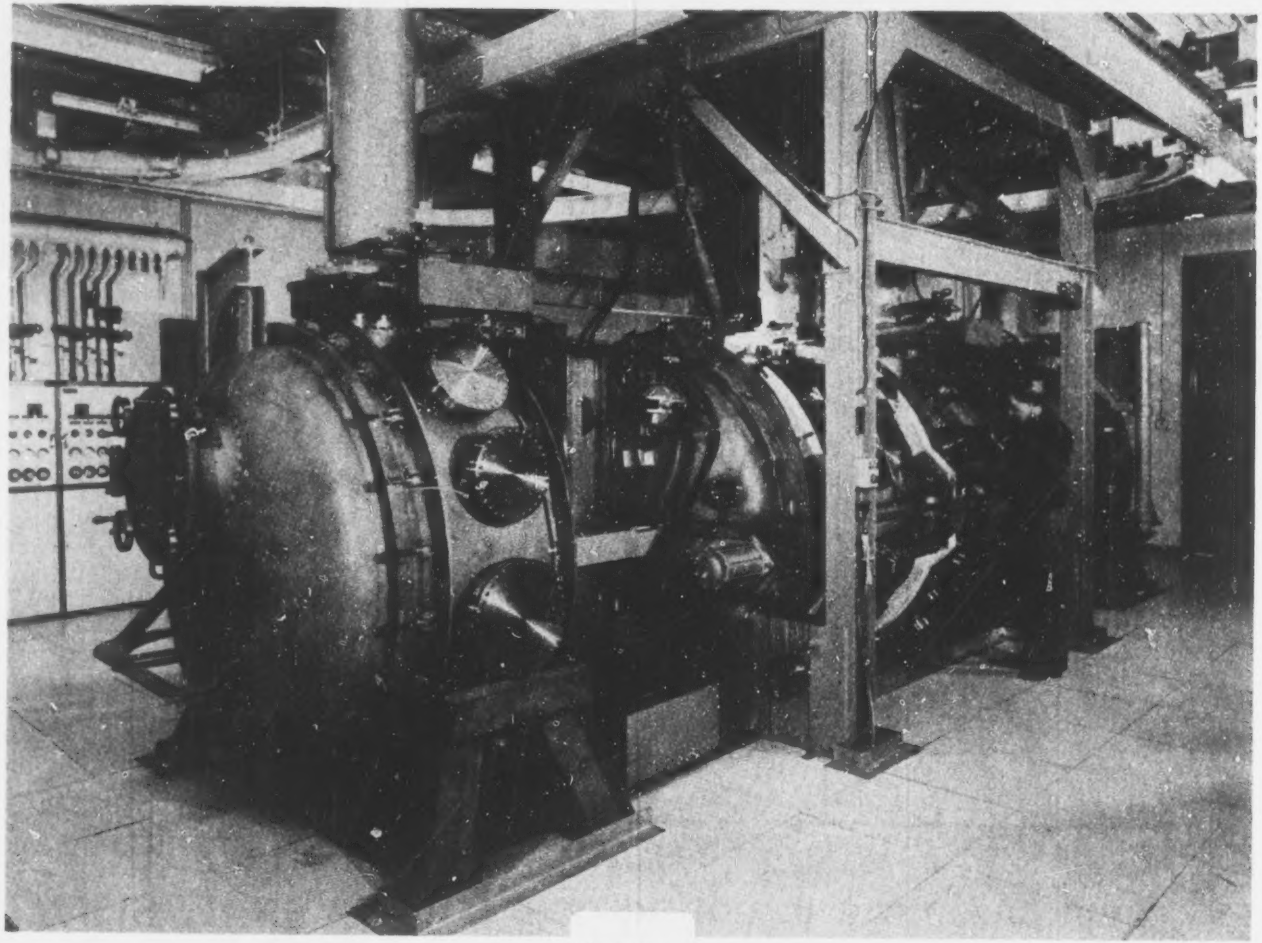
Now, what we would be doing in order to accomplish this? We built this isotope separation facility as shown here (viewgraph 4) at the laboratory, at which we got beneficial occupancy in last year—we will put in 20 percent of the laser in the system, but we will not install the large plant-scale uranium separator. What we will do is pipe the laser beam underground from this facility that I just showed you, all the way up to our existing uranium separator, which is about a kilometer away (viewgraph 5) that separator is at half scale and; it is only designed for short run times. That separator is shown here (viewgraph 6); it's called the MAR's facility. And that separator, if it had full laser power in it, is about 250,000 separator work units per year capacity. But we've only had 20 percent of the laser power, so the capacity is far reduced below the 250,000 separator work units per year. That is what we will try to accomplish for the 1985 process selection.



Viewgraph 4

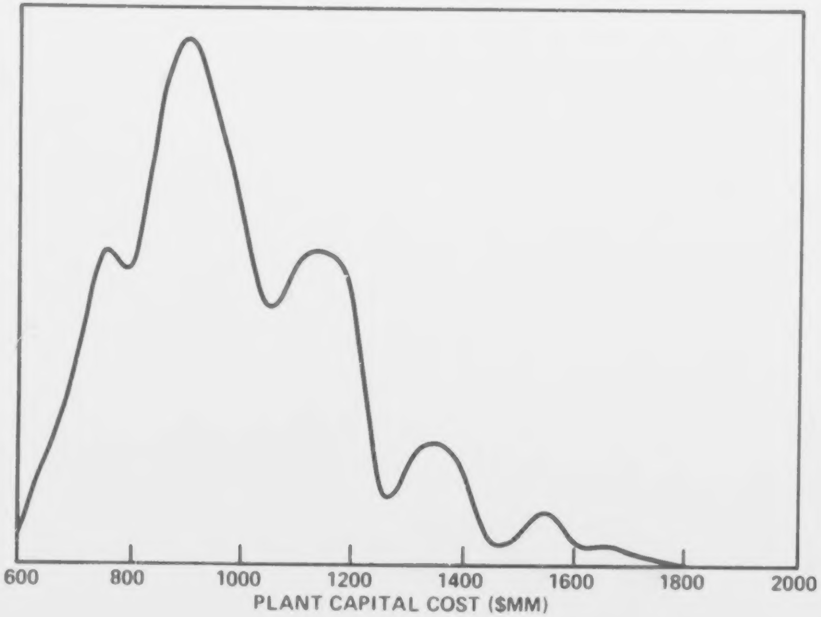


Viewgraph 5



Viewgraph 6

AVLIS MVSS results: distribution of projected plant capital cost ~9 million SWU/y



PLANT CAPITAL COST ($MM)	
*MINIMUM	720
MEDIAN	980
*MAXIMUM	1440
MODE	900

*MINIMUM AND MAXIMUM REFER TO THE MIDDLE 90 PERCENT INTERVAL

UNION CARBIDE

Viewgraph 7

Now you ask me, is that sufficient? I would say in the absence of a multibillion-dollar commitment to GCEP, and in the absence of a production line producing these centrifuges, that this would be more than an adequate demonstration for the technical community and the decisionmaking community on enrichment. I have a question as to whether this is an adequate level of demonstration of the technology and its cost factors, given the tremendous commitments that already exist to other technologies.

However, let me address for a moment the matter of cost. Two years ago we went through a process selection among the advanced technologies that were being proposed. The advanced technologies at that time were the plasma process by TRW, the molecular isotope separation process being pursued by LASL, and the AVLIS process being pursued at Livermore. And we went through what was probably, in the history of DOE, the most intense adversarial, refereed analysis of the technical risks and the economic risks and the uncertainties associated with these various three processes, and these charts are the output of that particular process selection activity.

This chart (viewgraph 7) shows the probability, the relative probability that a 9-million separator work unit per year AVLIS plant would cost the following amount of money. As you see, the most probable value people considered was that the 9 million separator work unit plant would be $900 million complete. Now, that's not incremental cost; that's buying the land, that's borrowing the money, that's building the plant, that's paying the interest during construction, and so forth. That's full industrial costing; no incremental gain. And so you see, the highest estimate anybody came up with at the 10 percent confidence level was about $1.4 billion, and the lowest number was about $720 million. So what you can see here, is the following—and we can talk about installing separative work at $100 million for 1 million separative work units 1 year capacity.

Now, what's the selling price today of separative work? The selling price today is $135. OK, 1 million separative work units is therefore $135 million. The cost of production from this would be about $25 million; and therefore, you see from the business point of view, this plant pays back its entire capital at today's prices in 1 year. I think that's just a stunning economic situation.

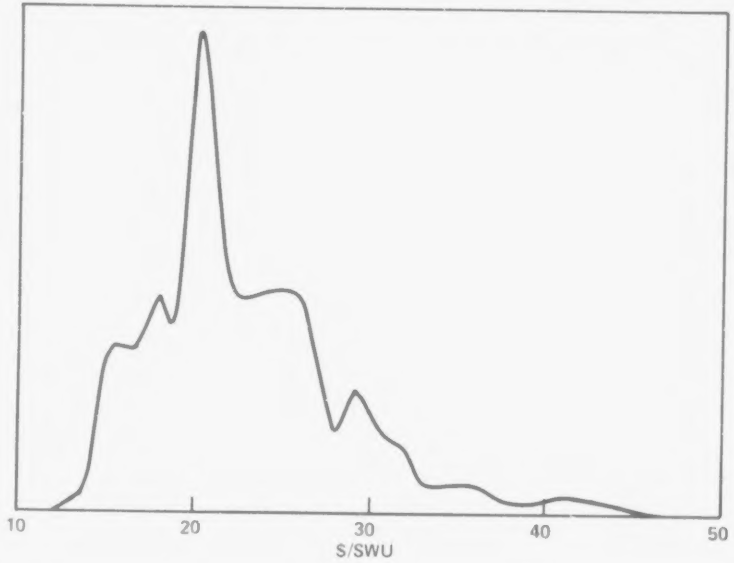
Now these, as I say, are not incremental costs, but full costs.

Now let me show you what people came up with as the analysis, the similar analysis on the price of separative work, having to do with all the technical and economic uncertainties. And that's shown here. (Viewgraph 8.) Again, the relative probability on the vertical axis; the price in dollars per SWU on the horizontal axis. The most probable number was $20 per separative work unit; the minimum number being $16, the maximum number being $33. These are not incremental numbers. These are everything: the cost, the full amortization on the plant, the interest on that money, the operating cost, and the maintenance of the facility. So I think you can see here that we're talking a technology that has striking economic advantages.

Now, the question is, Is this a flash in the pan or not? Well, for 9 years we have put together a full-up economic study of a plant.

Most of these studies have been carried out jointly with the nuclear division of Union Carbide, and this (viewgraph 9) is the history of those costing studies. And that is the price of separative work plus feed preparation has maintained pretty constant over the years in spite of all of the escalations, on the order of $25 per separative work unit. The tremendous reductions from our early designs were simply the fact that we gave up thermally heated sources and went to electron beam vaporizers.

AVLIS MVSS results: distribution of projected separative work cost ~9 million SWU/y



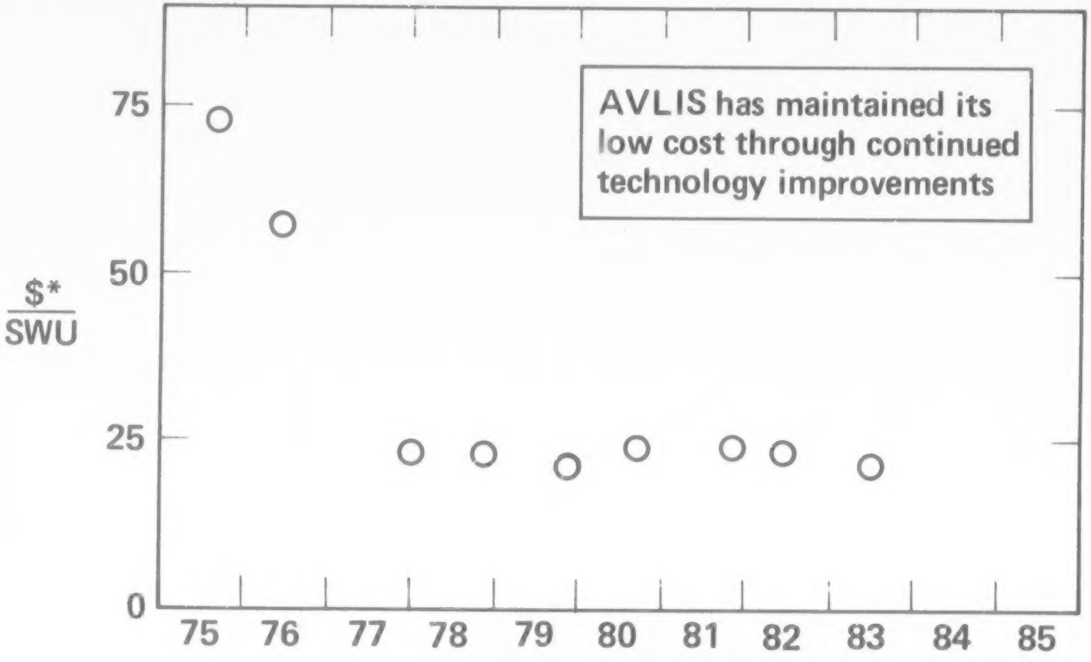
SEPARATIVE WORK COST ($/SWU)	
*MINIMUM	16
MEDIAN	22
*MAXIMUM	33
MODE	20

*MINIMUM AND MAXIMUM REFER TO THE MIDDLE 90 PERCENT INTERVAL

UNION CARBIDE

Viewgraph 8

History of AVLIS projected cost per SWU



AVLIS has maintained its low cost through continued technology improvements

*Renormalized to 1983 $

70-01-0284-0377

Viewgraph 9

2/84

AVLIS cost reduction/control

Improvements in special equipment can further reduce costs and/or represent a hedge against cost growth

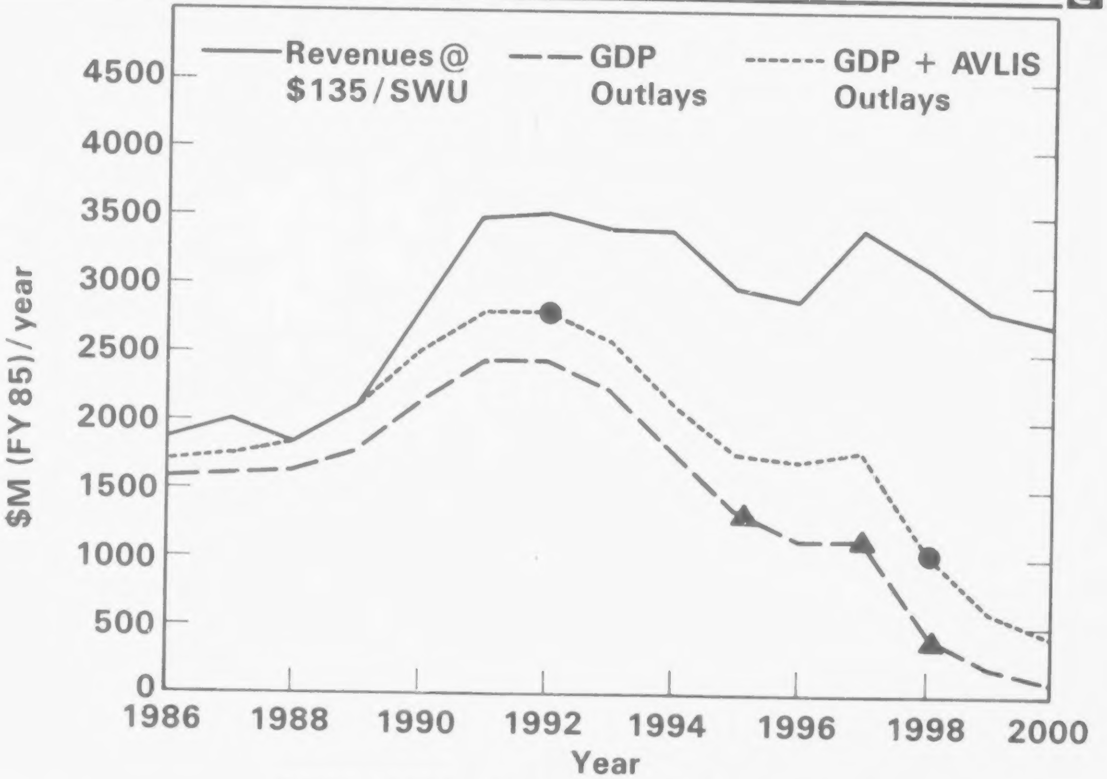
- Lasers
  - Increased power levels (3× to 5×)
  - Increased efficiency (2×)
  - Increased lifetime (2× to 4×)
- Separators
  - Increased throughput rates (2× to 3×)
  - Increased collector lifetime (2× to 4×)

These further improvements will lead to more separative work (from installed equipment) and hence lower cost

70-01-0284-0502

Viewgraph 10

AVLIS wins 1985 process selection



GCEP/AGC phaseout costs not included

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Viewgraph 11

Now, everybody always says, aw, well, gee, when you start out and it's a new technology you've got these wonderful ideas about how cheap it is; but when you really get into it you find out that costs get out of hand and so forth, and I realize that. You know, in any major project cost control, I think, is probably the most important issue. And the way cost control is done in a rapidly evolving technology like this is by having large leverage items that reduce the cost of individual things. (Viewgraph 10.) For example, we have two major components, the lasers and the separators. First of all, we have increased the power level of a given laser already by three times, and we think we may go to five times, for no increase in cost. That means you require one-third to one-fifth the amount of lasers. And none of that, for example, has been taken into account in the economic analysis I showed you. We have already demonstrated increased laser efficiency; that's not in our economic projections. And we have some approaches to the switch lifetime which will bring this cost down by a factor of two to four; that's not in any of the economic projections.

But what I want to show you here is that, because this is a very advanced technology, really a rapidly evolving technology, you're talking about improvements that are not 20 percent or 30 percent or 40 percent, but improvements that are 200 and 300 and 400 percent in very many individual areas of the process. Therefore we are confident that we can bring this technology in at the sort of costs that I have shown you because we have so much technological innovation that can go into it during the course of the process.

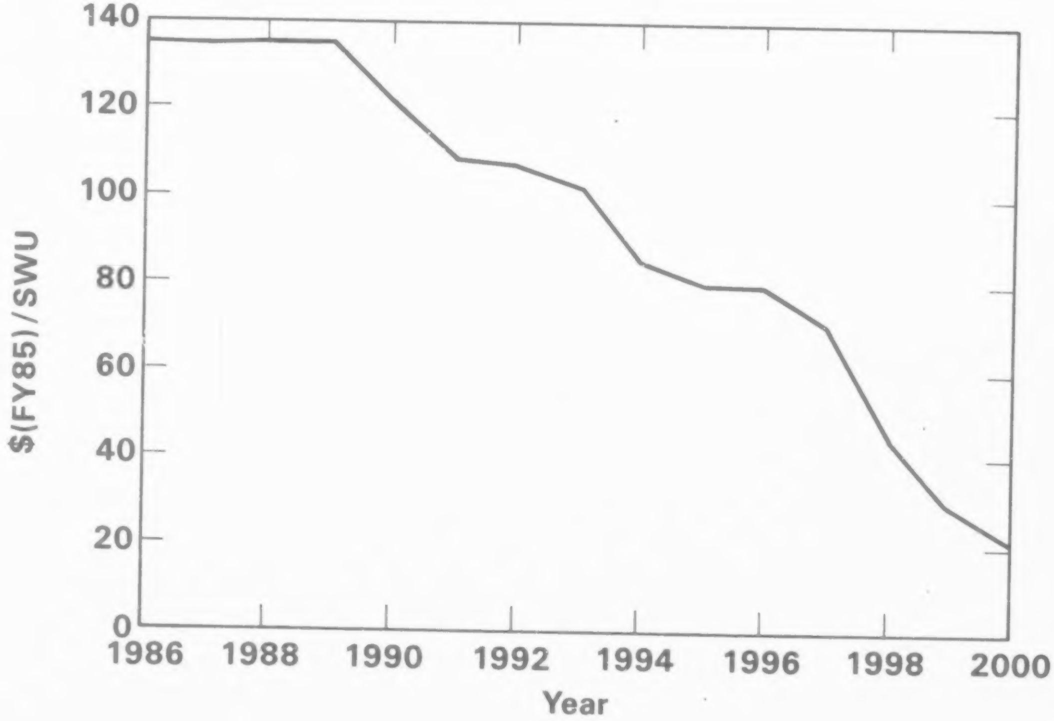
Now, as we understand DOE's approach, they want to go to 1985 and make a decision between AVLIS and the AGC program. We've been asked to put together scenarios as to how AVLIS could fit in this set of constraints; that is, that we will not require a net appropriation, that we go with the market that seems to exist, and so forth. We have done one of the analyses with the standard DOE cases, and this is an example of one scenario. What is shown here (viewgraph II)—this is the number of million dollars per year that the total enrichment enterprise is spending or taking in. This top curve is the new DOE projection of the civilian plus the Government enrichment revenues at $135 a separative work unit. This is the curve that John Longenecker showed you in previous testimony.

What we have shown with the lowest curve are the outlays necessary to run the gaseous diffusion plants in order to meet the early portion of that demand, and then later tailing off as the AVLIS production capacity comes in.

What I've shown with the next lowest curve is the full cost of implementing and operating AVLIS production capability. And what we are doing here is, we are implementing capability—this is the full-scale plant capability, reached in 1992—then we keep phasing up more capacity until, here's the second full-scale plant up here in, essentially, 1998. And that takes care of the entire demand. And these three points are the last years of operation of the three gaseous diffusion plants.

This costing is from the Oak Ridge Mecca Code on operating of diffusion plants and what they cost and taper down, and so forth. So you can see that the AVLIS technology could be implemented very easily within the strategy that DOE has laid out. This is certainly, by no stretch of the imagination, the only scenario, or even the one we're recommending. We haven't had a chance to study the situation enough to play off various variables against each other and see what works. But just to give you an idea of what that would mean to the consumer of separative work, I've shown here—this would be the price in 1985 dollars of separative work as a function of time, if you followed that scenario. As you see, (viewgraph 12) the price drops from in the order of $135 a separative work unit today to on the order of $20 a separative work unit—now, this is the selling price, not the production price—by the turn of the century if we implemented the strategy I just outlined. And so you can see the dramatic cost reductions that are involved here.

Price required to meet all planned expenditures



70-01-0284-0498

Viewgraph 12

And in here there is no assumption of incremental costs. This is a full cost analysis with normal business principles; that is, you borrow the money, you pay interest on it, you fully amortize the plant, and you pay current interest rates and so forth. So I think that gives you an idea of what's possible. The only reason the prices here of $135 per separative work unit in the early years is to cover the costs of closing out the centrifuge program if DOE made the decision to do that, and to cover the demand charges, you know, that TVA is levying on the enterprise at that particular time.

Now if I could, I would like to make one last comment, and that's a comment that regards the whole issue of costs. I hadn't intended on making any comment about the AGC program, but I noticed that AVLIS has now become real enough to many people, so my worthy competitors decided it was necessary to address the issue of AVLIS. It's nice to see that we're taken seriously for the first time. But at any rate, I think that the comment Mr. Rowan made with regard to the importance of seeing AVLIS through a complete and economic demonstration before a commitment is made is a well-taken comment. But I think it is a much more well-taken comment with regard to the AGC program and the price of separative work from set V machines. In AVLIS we're talking about capital commitments that are not particularly great. In the centrifuge program the capital commitments are enormous. It would seem to me that it would be extremely important to the long-term competitiveness of the United States to really end-to-end evaluate the real cost of set V centrifuge technology in an optimized way, and AVLIS technology. I'm not sure what the best way of doing that is, but I think it is very important that the costs of both be compared.

Now, there's been a lot of discussion of, what's the arithmetic for comparison? Let me just suggest a very simple one, and then it's easily modified. Just look at the cost of going out into an empty field and building 9 million separative work units or 27 million separative work units, whichever you like, with any advanced technology from scratch. Going in there, raising the capital, paying interest charges, amortizing the plant, operating it through its lifetime, and look at what that cost is. That's the way business would look at an enterprise like that if indeed enrichment were going to be run as a business enterprise. Having looked at that comparison, I think you will find that it is such a strikingly black and white comparison between centrifuge technology and laser technology, that it's almost no issue. At that point then you can decide how much Government subsidy one wants to put into the enrichment enterprise, how much away from a normal business enterprise one would like to take, how much risk reduction one would like incurring extra costs, and so forth. But I think this is one very simple method of comparing economics.

That concludes my statement and I'd be glad to answer any questions.

[The prepared statement of Dr. Emmett follows:]

AVLIS Uranium Enrichment Program

Statement prepared for
Subcommittee on
Energy Research and Production
House Committee on Science and Technology

February 1984

University of California
Lawrence Livermore
National Laboratory

AVLIS Uranium Enrichment Program

Statement prepared for
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by
John L. Emmett
Associate Director for Lasers
Lawrence Livermore National Laboratory

February 1984

In January, 1983, both Lawrence Livermore National Laboratory (LLNL) and Union Carbide Corporation - Nuclear Division (UCC-ND) proposed to DOE that a demonstration of Atomic Vapor Laser Isotope Separation (AVLIS) at production scale could be achieved by 1987 and that such a demonstration would conclusively validate the economics of this uranium enrichment process. UCC-ND supported this proposal based on the fact that AVLIS showed the greatest potential for low cost Separative Work Units (SWUs) in the 1990s. They recommended that AVLIS be funded at the highest priority within DOE revenues after primary production requirements were met. This proposal was supported by DOE in April, 1982, insofar as the proposed AVLIS program objectives were concerned.

The continued erosion of sales projections since 1982 has led DOE to request that we look at alternative, lower-cost, intermediate-scale AVLIS demonstrations which, though short of the full production-scale demonstration, would provide a better basis for selection than exists today. Figure 1 gives a summary of three substantive options which are available, according to the selection year and the cumulative costs from beginning FY84 through the end of the selection year. We cannot bring full-scale systems on line prior to FY86, and we cannot achieve extended operations of this equipment prior to FY87. Thus a process selection prior to FY87 will be based on limited operations and economic demonstration, and a selection prior to FY86 will, in addition, be based only on sub-scale systems.

However, the results we have achieved to date convince us that the AVLIS process will meet or exceed its cost performance goals. Though the existing equipment is sub-scale, the scaling up to production conditions involves the combination of many sub-scale enrichment cells into a large multicell array. The AVLIS enrichment concept for a single enrichment cell is illustrated in Figure 2. As summarized in Figure 3, we have demonstrated single cell enrichment performance, and test data show that when many such cells are integrated into a multicell collector array the enrichment performance can be maintained. The objective of the proposed program was to further validate these results in a production scale separator pod which can be operated for multiple production cycles in order to establish operating economics by 1987. Construction of the building at Livermore required to carry out the demonstration work was completed in April, 1983. An aerial photo of the construction site is shown in Figure 4. An artist's conception of the special equipment to be installed in this facility is shown in Figure 5, illustrating production-scale laser and separator systems.

In the accelerated selection plan, requiring selection in mid-FY85, we cannot complete installation of all the special equipment at production scale. We can install about 20% of the total laser system and, through the use of a pipeline, this laser power can be transmitted to an already existing uranium separator facility. An aerial photo of the pipeline installation, which was completed last year in order to meet Defense Program requirements, is shown in Figure 6. The 1/2-scale separator facility which will receive the transmitted light beam is shown in Figure 7. In addition to these facilities, there is a materials handling facility currently being activated at Oak Ridge, as shown in Figure 8, and we expect to operate large-scale collectors around the clock within the next 12 months so that substantial information will be available to evaluate the uranium processing technology.

Our confidence in the AVLIS process has steadily increased not only because of the demonstrated high separative efficiency, but also because of the demonstration of production-scale components that can be fabricated at low cost and can operate with acceptable lifetimes. In the case of the lasers, we have shown the complete functional integration of the technology, thus verifying system operability as well as component operability. Today our existing laser system operates 24 hours per day, five days per week in support of ongoing experiments. A similar functional integration effort is under way for the separator equipment, and we expect to demonstrate system operability in the coming year. Figure 9 indicates the technical tasks we hope to achieve prior to the FY85 process selection.

Along with the work on component development and system integration, we have done conceptual designs and cost evaluations of AVLIS production facilities each year for the past nine years. The level of detail in these studies as well as the technology has continued to improve. Figure 10 shows how the projected cost of AVLIS production ($/SWU) has varied. In the first two years, showing the relatively high estimates, the designs were based upon resistively heated crucibles to produce uranium vapor; whereas all subsequent designs were based upon the use of electron beam vaporizers. It is clear that in spite of inflation and the evolution from initial scientific concepts only, up to fairly detailed designs today, AVLIS has maintained its low cost potential through continued technology improvements. We fully expect this trend in technology improvement to continue so as to reduce cost further and/or prevent cost growth as we move toward production systems. Figure 11 gives some typical examples of how these improvements might occur in subsequent cost projections for the special equipment. The increased laser power levels (and efficiency) and the increased separator throughput rates can lead directly to a reduction in capital cost; the increased lifetimes of these systems can lead directly to reductions in operating costs. It is our belief that the AVLIS process can achieve total production costs in the range $10-$40/SWU in the early 1990s if the program receives adequate support.

Of course, there is uncertainty in these projections, and we have tried to make evaluations of this uncertainty. Utilizing the 1982 design, we carried out an extensive evaluation of the cost and performance variations which could occur if this design were utilized for the final production systems. The importance of this work is that the design, cost, and performance data were critically evaluated in a peer review effort involving TRW and Los Alamos National Laboratory (LANL). The evaluation was managed by DOE, and the analysis was performed by UCC-ND in a support role to DOE. Figures 12 and 13 summarize the results for plant capital cost and production cost ($/SWU), respectively, of a 9 million SWU/year facility. What these figures show is the probability that a particular overall cost will be realized given the uncertainties in the underlying design, performance, and cost data for individual components of an AVLIS production plant. One can see that the most probable capital cost is about $900 million (or $100 million per million SWU/year), and there is 90% confidence that the capital cost will lie in the range between $720 million and $1,440 million. Similarly, the most probable production cost is about $20/SWU, and there is 90% confidence that the production cost will lie in the range between $16/SWU to $33/SWU. Though the 1982 design is somewhat out of date, the continued improvements in technology since that time give us complete confidence that the 1985 design will be at least as cost effective as earlier designs. There are two major components in the cost of a kilogram of enriched fuel -- the cost of separative work and the cost of natural uranium feed. For each cost of feed and separative work there is an optimum tails assay which minimizes the cost of the final enriched product. This optimization is shown in Figure 14. The AVLIS process can be easily configured to operate at any tails assay. It is important to note that the low SWU cost (~$20/SWU) of AVLIS would permit the economic utilization of the very large tails (~0.2% assay) stockpiles (Figure 15).

The detailed criteria employed in FY85 process selection are of great importance. If enrichment is to be operated as an economically sound, competitive business enterprise, then the criteria for process selection must reflect that essential character. Each competing technology ought to be evaluated as if it were a new stand-alone operating division of the enrichment enterprise. It is particularly important that the costs be evaluated in this way to avoid making a decision which is short-term expedient (i.e., ignoring sunk costs) but which may place the enrichment enterprise in a very difficult position in the late 1990s from foreign competition with advanced technologies. The economic evaluation should be carried out according to modern business practices using the following key factors:

- cumulative cash flow
- net present value of cash flow
- return on investment (instead of net profit)
- realistic depreciation schedules (instead of production weighted)
- vulnerability to adverse trends (technological or market).

In spite of the great promise of the AVLIS process, we recognize that the near term financial problems being faced by the uranium enrichment enterprise make it difficult to proceed rapidly with the AVLIS technology. In order to make a contribution to the solution of this problem, we have performed a conventional financial analysis on the overall enterprise with the assumption that AVLIS is selected in 1985. We used the most recent forecast of sales and price from DOE. Figure 16 shows the total revenues and costs for the enterprise assuming AVLIS is rapidly deployed to displace gaseous diffusion plant (GDP) capacity. The circles on the curve indicate the first year of production from two successive AVLIS production plants, and the triangles on the curve indicate the last year of production from each of the three GDPs.

No costs for phase-out of the GC program (both GCEP and AGC) are shown on Figure 16. The best estimate we have for phase-out of the GC program is approximately $600 million. The rate at which this program is phased out must be consistent with the $135/SWU price ceiling. Based on the data available at this time, our financial analysis indicates that only about $400 million would be available in FY86/87 for phase-out of the GC program. There is currently an effort under way within DOE and UCC-ND to evaluate alternative modes of operation for the GDPs which could potentially reduce costs by several hundred million dollars over the next few years. If this effort proves successful, and we are told it probably will be, then it would clearly be possible to phase out the GC program by the end of FY87. This analysis shows in Figure 17 one potentially viable plan to stay within the price ceiling in the next few years and achieve a price reduction prior to 1990. Whether this specific plan is followed or not, it is clear that the AVLIS program offers the potential to put the uranium enrichment enterprise in a strong competitive posture in the 1990s. We recommend this plan for the Committee's consideration and hope it will be useful in your deliberations.

Thank you for your continued support and the opportunity to present this information to you today.

AVLIS process selection options

Selection Year	Demonstration Status	Cost FY84 Through Selection*
FY85	— Sub-scale systems Lasers — 20 %; separator — single cell — Operation duration ~10 hours enrichment; 100 hours collector — Limited economic data	$180M
FY86	— Full-scale systems Lasers — 100 %; separator — full multicell — Limited operation — Extensive economic data	$270M
FY87	— Full-scale systems — Full plant cycle operation — Conclusive economic demonstration	$400M

*Production plant activities limited to conceptual design and cost analysis.

Figure 1

Atomic vapor laser isotope separation — major systems

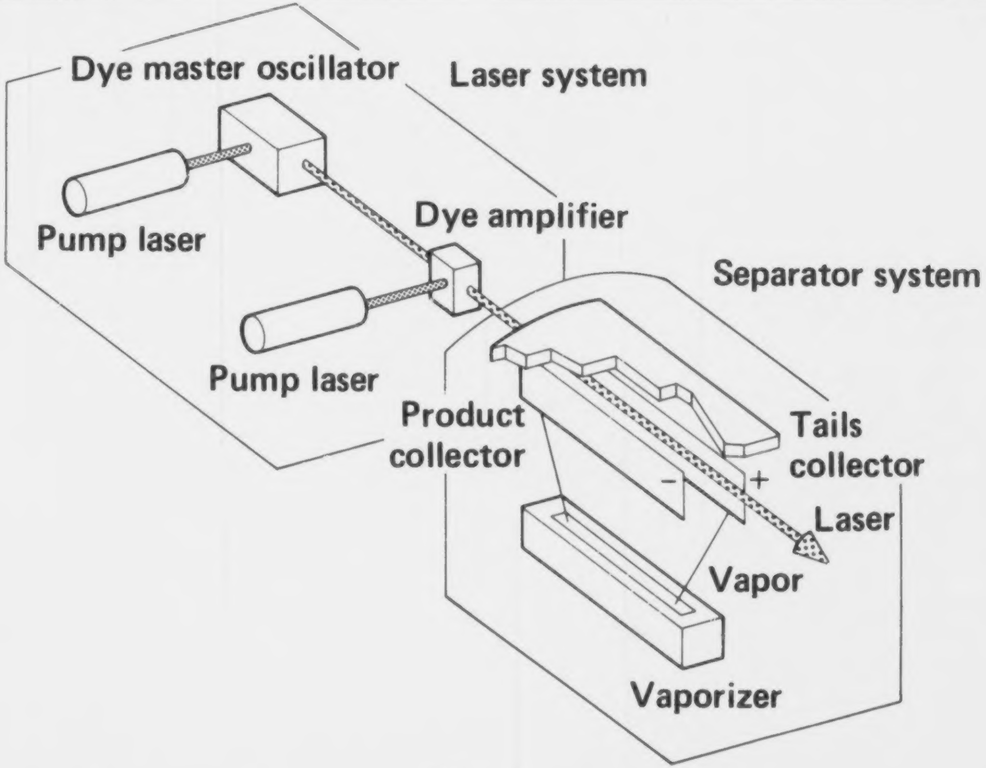
Dye master oscillator
Laser system
Pump laser
Dye amplifier
Separator system
Pump laser
Product collector
Tails collector
Laser
Vapor
Vaporizer

Figure 2

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9/83

AVLIS development status — enrichment performance

- Single cell separative work performance has been validated in a series of integrated mass balance demonstrations

- A series of multicell tests have shown that single cell performance can be maintained in large multicell arrays

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Figure 3

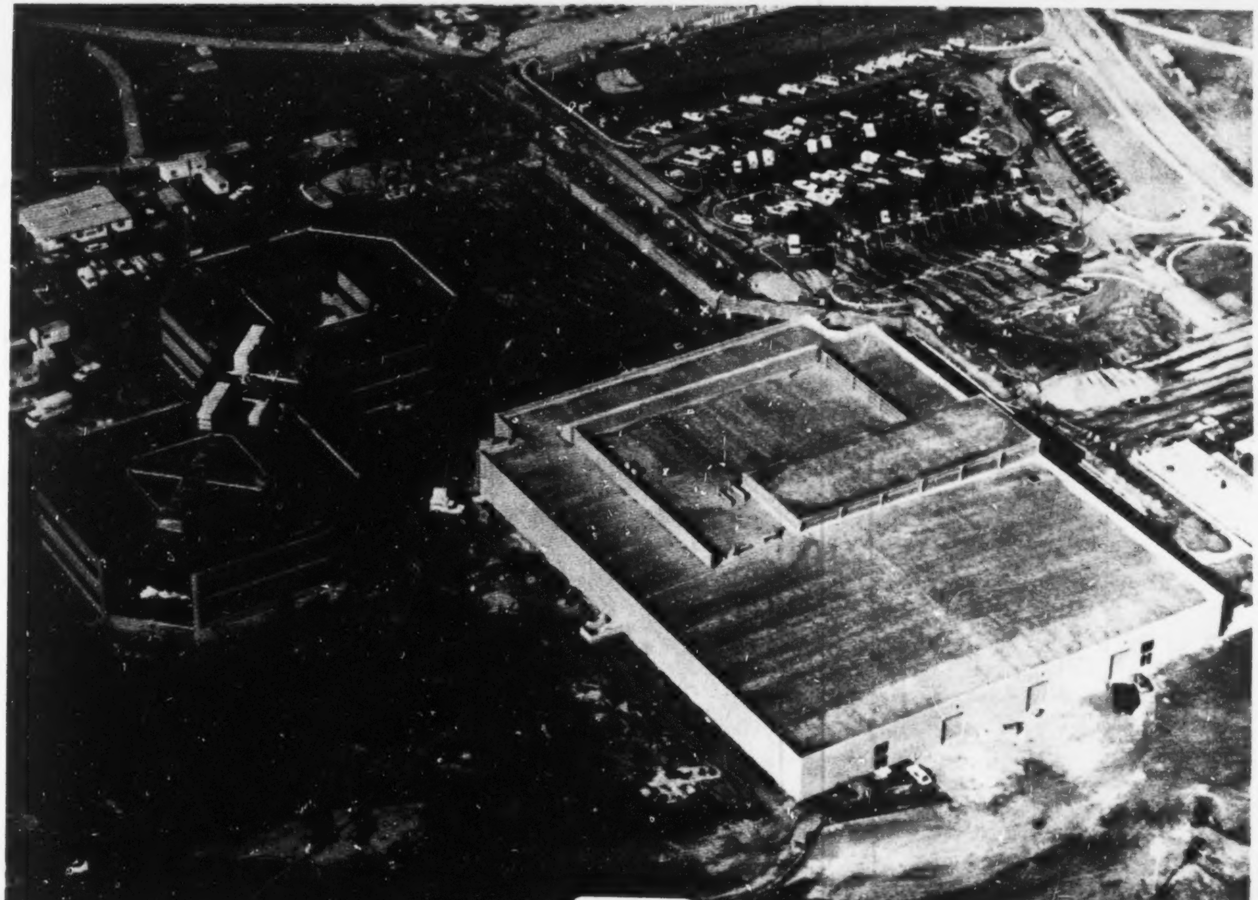
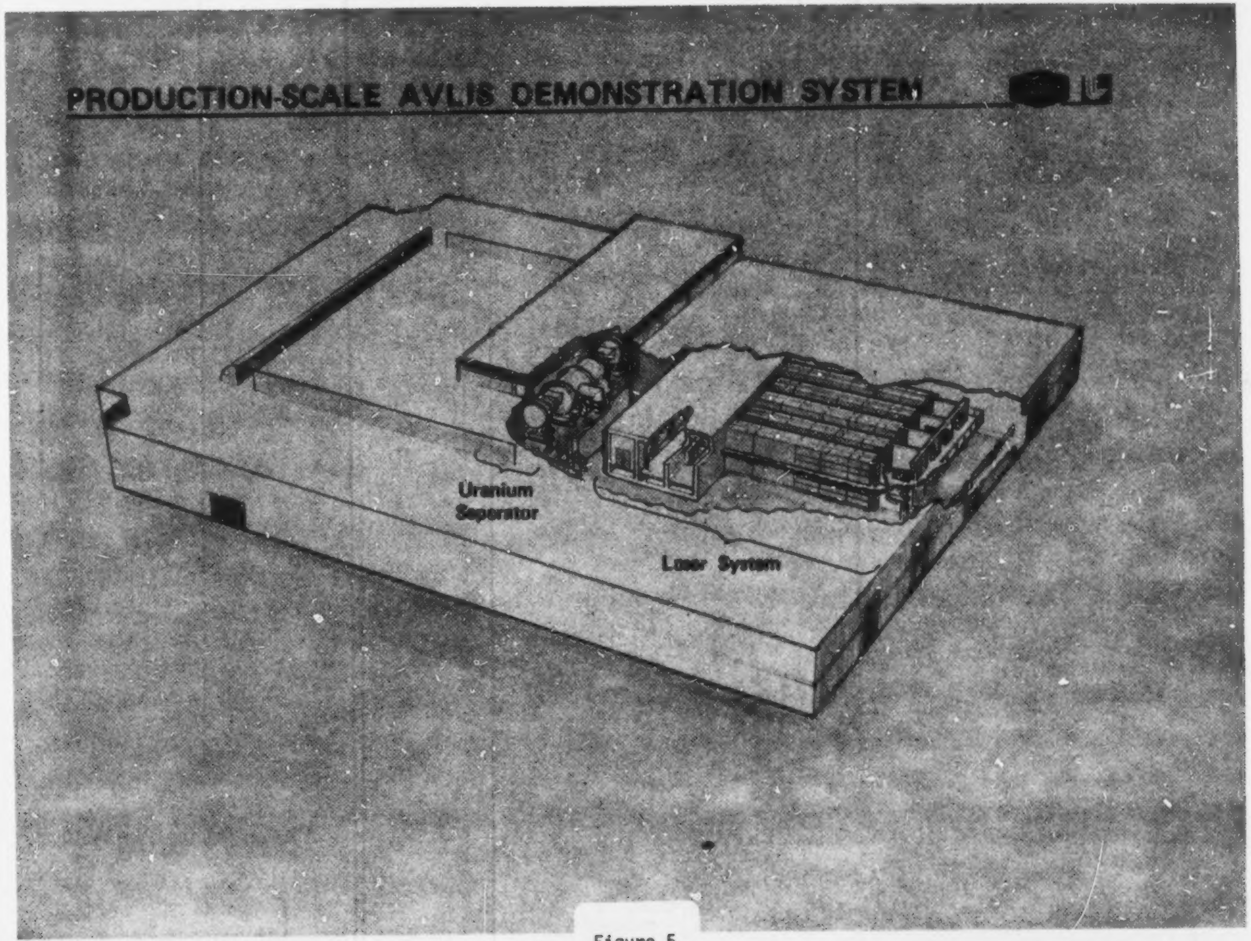


Figure 4



PRODUCTION-SCALE AVLIS DEMONSTRATION SYSTEM

Uranium
Separator
Laser System

Figure 5

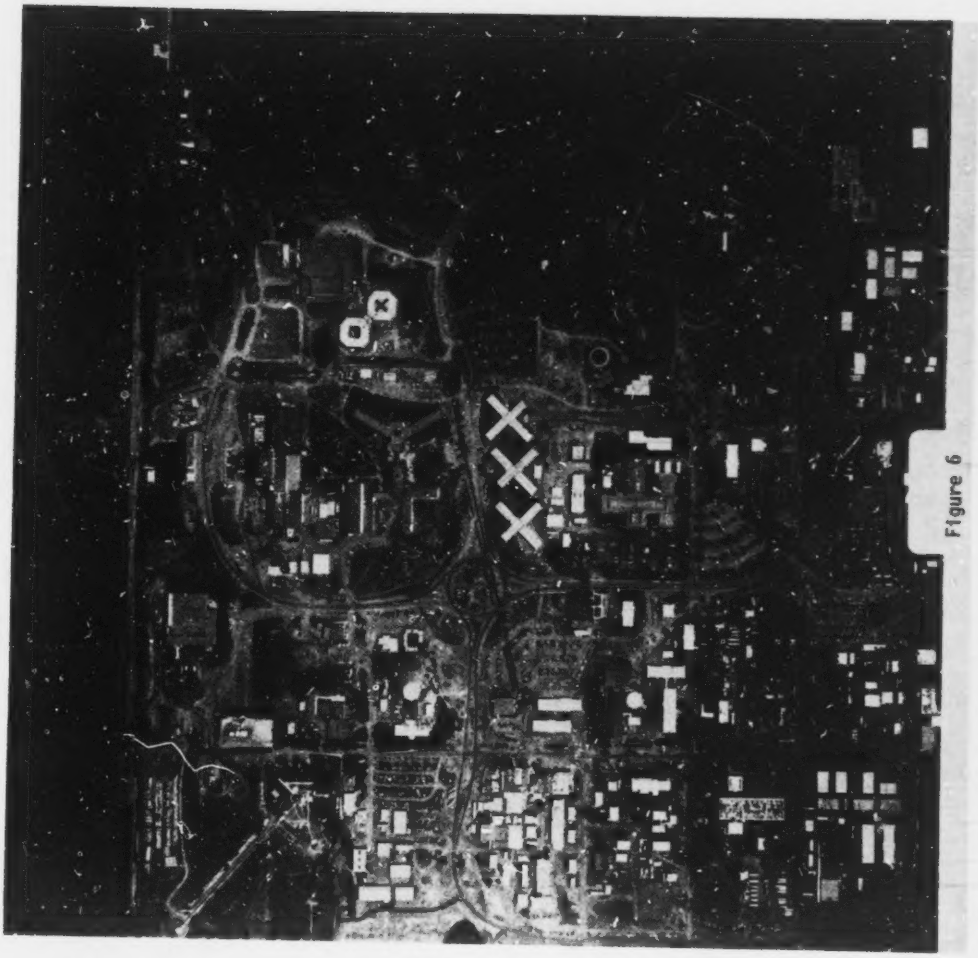


Figure 6

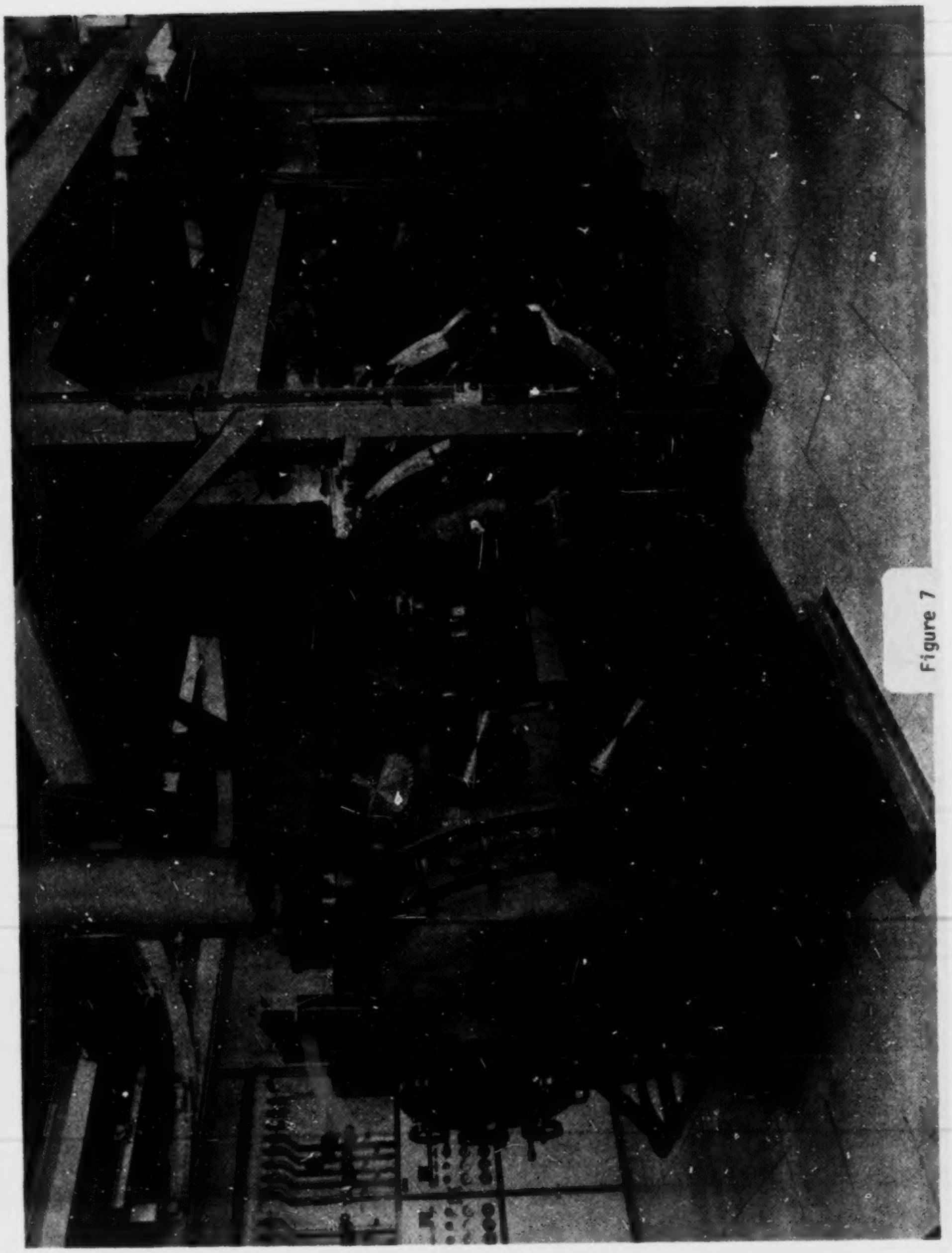


Figure 7

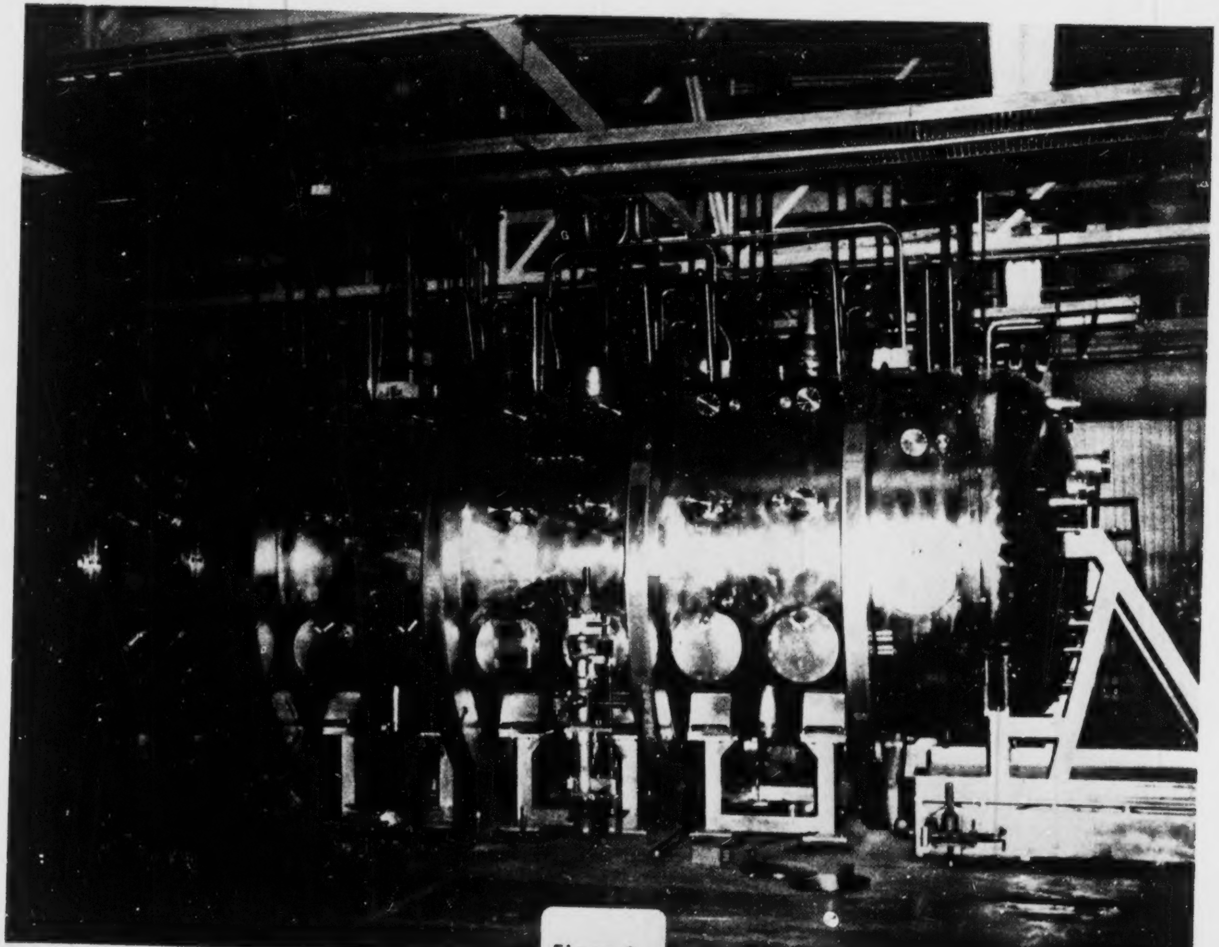


Figure 8

AVLIS Program technical objectives prior to FY85 selection

- Enrichment demonstration
  - $>$1000 SWU/year (laser repetition rate corrected) one or more cells
  - Plant separator environment; short run times
- Functional integration of plant systems
  - Liquid extractor/collector; multicell
  - Laser system: plant waveform, $\geq$500 watts
  - Laser/separator integration; beam transport and separator optics
- Component and system reliability
  - 100 hour collector run
  - 1000 hour high power copper vapor laser operation
- Plant cost report

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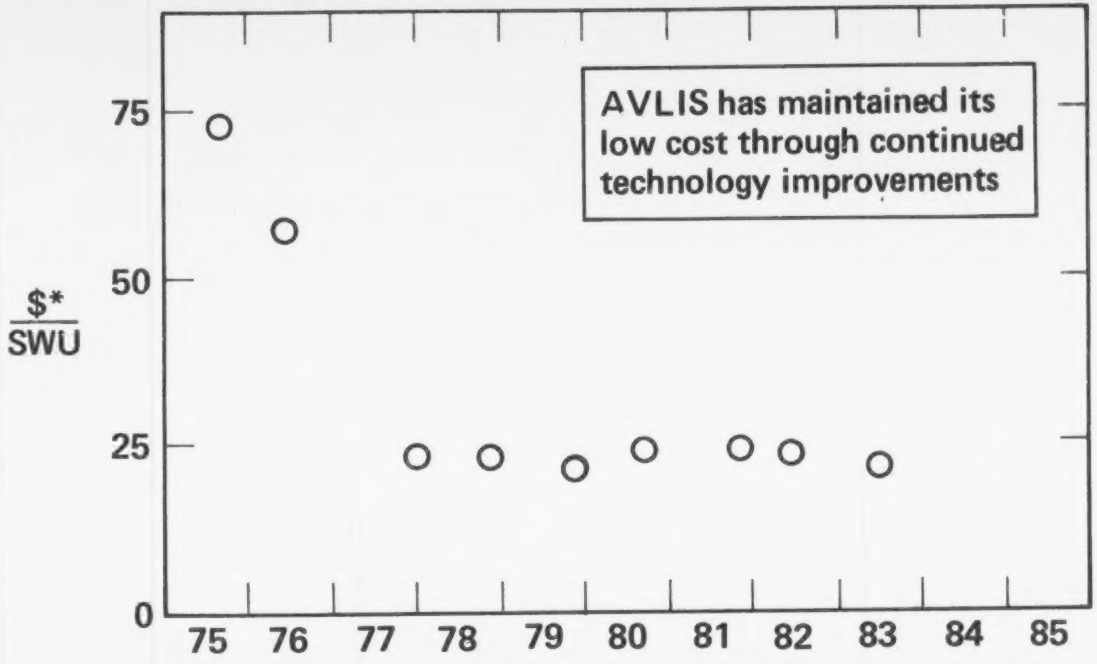
Figure 9

History of AVLIS projected cost per SWU



AVLIS has maintained its low cost through continued technology improvements

*Renormalized to 1983 $

70-01-0284-0377

Figure 10

2/84

AVLIS cost reduction/control

Improvements in special equipment can further reduce costs and/or represent a hedge against cost growth

- Lasers
  - Increased power levels (3× to 5×)
  - Increased efficiency (2×)
  - Increased lifetime (2× to 4×)
- Separators
  - Increased throughput rates (2× to 3×)
  - Increased collector lifetime (2× to 4×)

These further improvements will lead to more separative work (from installed equipment) and hence lower cost

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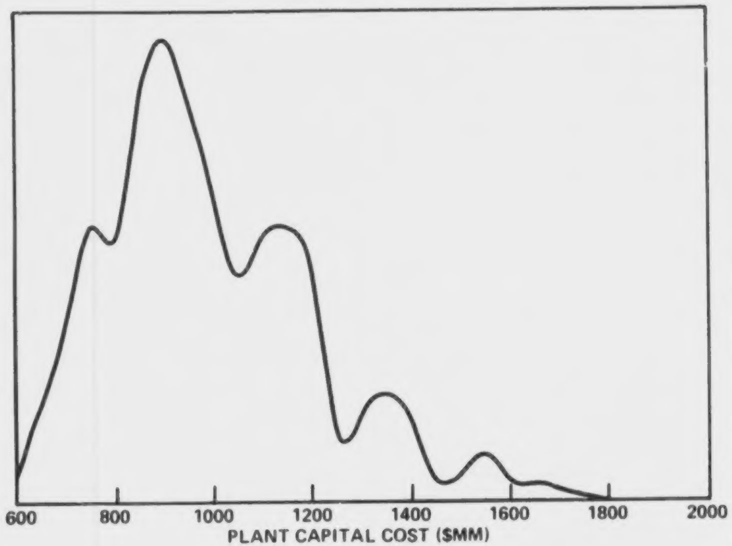
Figure 11

AVLIS MVSS results: distribution of projected plant capital cost ~9 million SWU/y

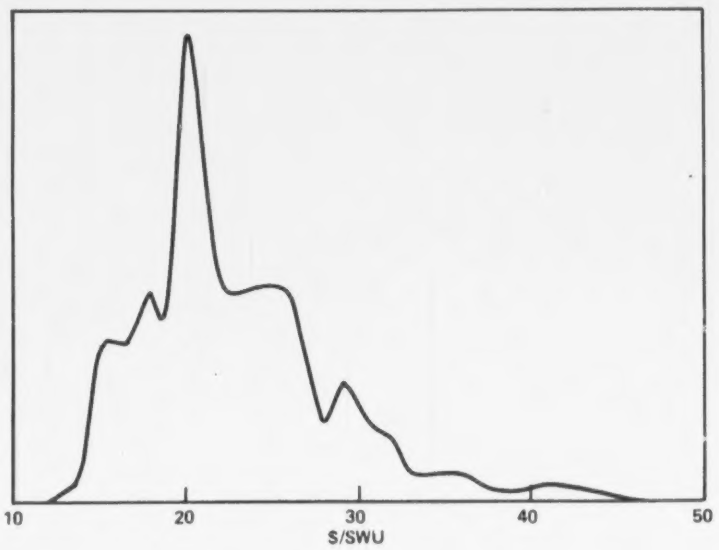


PLANT CAPITAL COST ($MM)	
*MINIMUM	720
MEDIAN	980
*MAXIMUM	1440
MODE	900

*MINIMUM AND MAXIMUM REFER TO THE MIDDLE 90 PERCENT INTERVAL

Figure 12

AVLIS MVSS results: distribution of projected separative work cost ~9 million SWU/y



SEPARATIVE WORK COST ($/SWU)	
*MINIMUM	16
MEDIAN	22
*MAXIMUM	33
MODE	20

*MINIMUM AND MAXIMUM REFER TO THE MIDDLE 90 PERCENT INTERVAL

Figure 13

Minimum cost of ore and separative work in 1 kg product (3% U^{235})

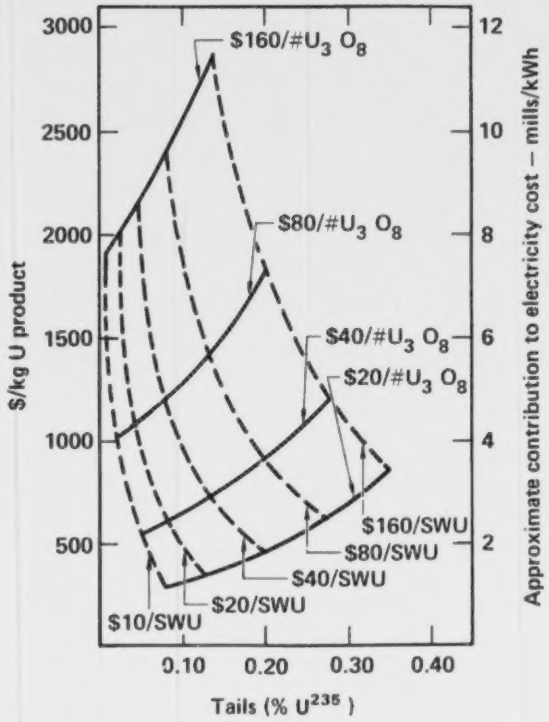


Figure 14

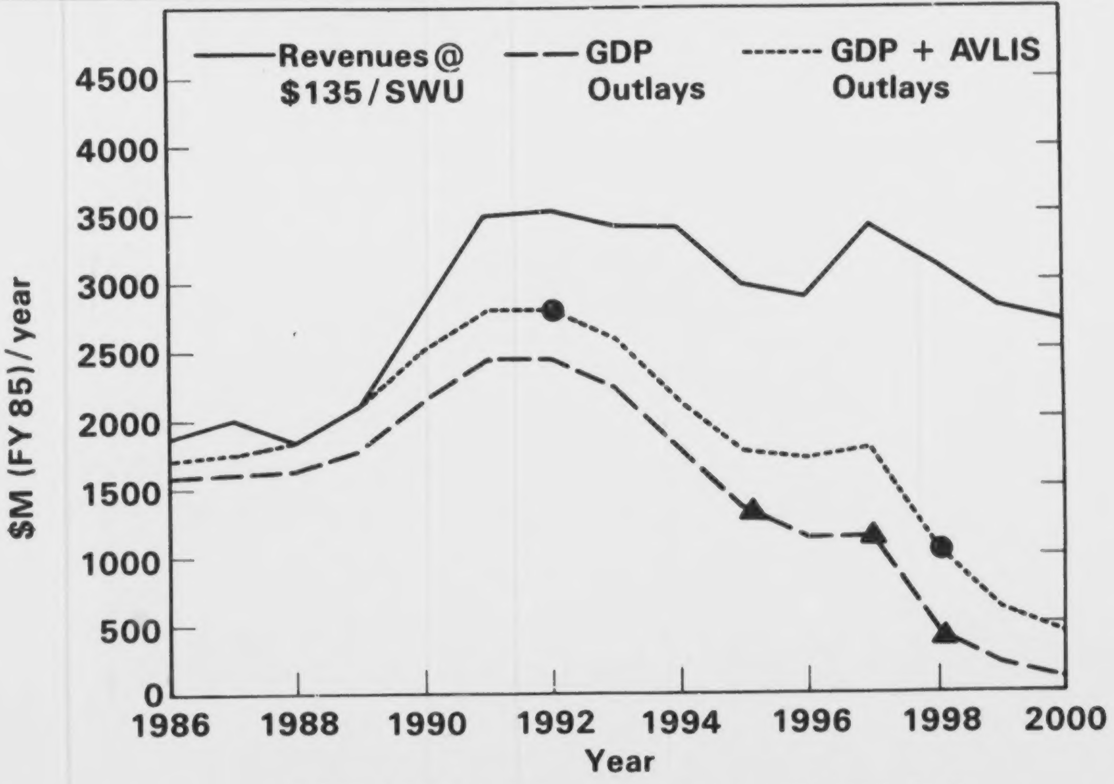
AVLIS operating tails assay

- AVLIS can easily be configured to operate at any tails assay with little (~10%) change in SWU cost
- AVLIS can minimize product cost by operating at the optimum tails assay determined by the relative cost of feed to enrichment
- Low SWU cost (~$20/SWU) of AVLIS permits economic utilization of existing tails stockpiles (~0.2% assay)

70-01-0284-0501

Figure 15

AVLIS wins 1985 process selection



GCEP/AGC phaseout costs not included

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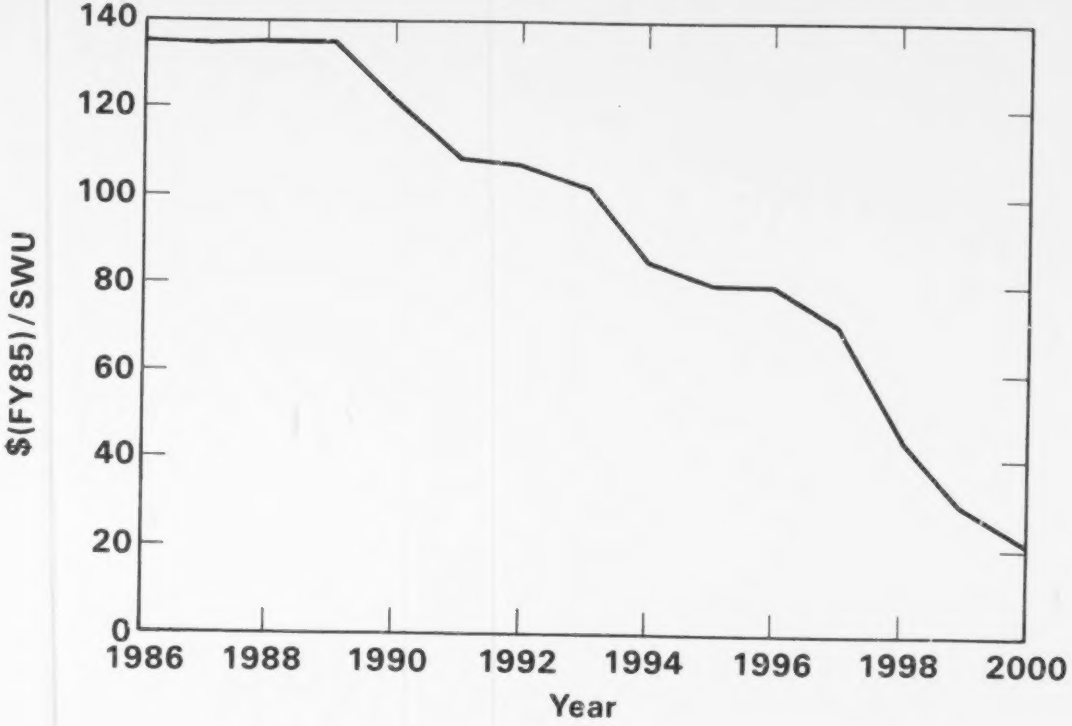
Figure 16

Price required to meet all planned expenditures



70-01-0284-0498

Figure 17

Mrs. LLOYD. Thank you very much, Dr. Emmett.

Mr. McWhorter, you may proceed.

STATEMENT OF WILLIAM C. McWHORTER, PROGRAM MANAGER, ADVANCED GAS CENTRIFUGE PROGRAM, UNION CARBIDE CORP.

Mr. McWHORTER. Thank you, Madam Chairman.

Madam Chairman, members of the committee, it is a pleasure for me to be here today and describe the advanced gas centrifuge, or AGC, development and design program. The objective of the AGC program is to develop and demonstrate a centrifuge having a separative capacity well above that of the initial gas centrifuge enrichment plant or GCEP machine. The initial GCEP centrifuge, the set III centrifuge, represents a demonstrated technology targeted to be more economical than gaseous diffusion. The AGC is an extension of that technology which will provide centrifuges for use in GCEP which will produce separative work at less than half the cost of them from existing gaseous diffusion plants.

As requested, I will describe the AGC development program and discuss the schedule for demonstration of this technology, the program funding, and the plans for an early deployment at GCEP.

The development and design program for the AGC is directed toward a target of 600 SWU/yr machine separative capacity as compared to 200 SWU/yr for the initial GCEP centrifuge. This advanced machine, which is designated the set V centrifuge, is being developed by a joint effort involving a team that has many years of experience in centrifuge development and in providing the centrifuges currently being installed at GCEP. This team consists of the AiResearch Manufacturing Co., Boeing Engineering Co., Southeast, Electro-Nucleonics, Goodyear Aerospace Corp., the University of Virginia, and the Union Carbide Corp., Nuclear Division. Union Carbide has been selected by the Department of Energy as the technical integrator for AGC development and design.

The improved separative performance targeted for the AGC is achievable by exploiting the capabilities of advanced materials which can be used in the construction of the centrifuge rotor. This will permit the operation of the rotor at significantly increased speed, resulting in increased capacity and reduced cost of SWU's. This is achievable since the separative output of the centrifuge increases very rapidly with an increase in rotor peripheral speed.

Starting with a limited material development and evaluation effort in 1982, dramatic progress has been made to date which confirms the potential for advanced material rotors to operate at speeds sufficient to produce the significantly higher SWU targets of the AGC program. In the past year material development has progressed from the sample evaluation stage to the fabrication of full-sized rotor tubes. Work to date has indicated that production of these rotor tubes can be accomplished with a consistency and an ease of fabrication comparable to that for rotors of the present set III centrifuge. At present, full-sized rotor tubes of advanced material have been fabricated by all three of the program participants who currently manufacture set III rotors. Thus, the major objection of the adaptation of basic set III manufacturing techniques to the set V advanced centrifuge machine has already been successfully accomplished.

In addition, other significant technical achievements have been made. These include the operation of a full-length advanced material rotor at speeds greater than set III, the qualification of various centrifuge assemblies for operation in prototype AGC tests, and significant demonstrations of the candidate advanced rotor suspension systems.

In the period between now and the end of this fiscal year, AGC rotor tubes will be assembled with other centrifuge components and tested at intermediate speeds which are significantly above the set III speed in order to gain important technical data necessary to guide the finalization of the higher speed AGC design. This information will relate to the rotor and suspension operating characteristics, rotor assembly design, internal gas flow management, thermal control requirements, and the verification of performance models used in centrifuge design and operation.

In late calendar 1984, testing will then begin on centrifuges at full-AGC speed. This will allow the determination of high-speed operating characteristics, validate the performance at full-scale, and provide a demonstrated basis for the GCEP machine design in April of 1985.

Based on information available in April 1985, DOE intends to select either AGC or the atomic vapor laser isotope separation process, AVLIS, for demonstration. After that point in time, AGC work would move into the engineering and production phases of the program. Centrifuges of the production prototype design would be used to optimize separative performance during 1986 and, subsequently, a design package would be issued for the production of 30 centrifuges for reliability testing. Also, limited production of additional machines for early deployment in GCEP is being considered.

By 1987, several prototype AGC machines would have been tested for approximately 1 year and would be expected to be well characterized as to separative performance and operating characteristics. Reliability of the advanced materials would have been evaluated in accelerated testing, but full machine reliability testing would have just been initiated. The production and operation of 30 centrifuges to gain both operability and reliability information can be expected to lead to some design advancements and also to an upgrading of the production design package in the 1987–88 time period. The production of set V machines at a low level and their deployment into GCEP in 1987 would appear to be very attractive in that it would permit an early and orderly shift by the centrifuge manufacturers from production of set III to production of set V machines. This would provide for early demonstration and utilization at GCEP of the low-cost separative work technology.

I would like now to discuss, as requested, the impact that additional funding could have on this program. We believe that the fiscal year 1985 funding that DOE is requesting will allow us to meet the 1985 program milestones. Additional funds would provide for increased schedule assurance. This additional funding would permit the parallel pursuit of certain alternate assembly designs in early fiscal year 1985 and would also provide backup test hardware which could prevent possible delays in the evaluation of the candidate full-speed AGC designs. Specifically, additional funding could be helpful in providing a program for a backup rotor suspension, other hardware for use in principal candidate machine tests, and for material optimization for the specific applications of this program.

In summary, the AGC development and design program is moving aggressively toward the objective of a significantly improved centrifuge for deployment at GCEP. Progress to date has been excellent and has confirmed the potential of advanced material for significantly increasing centrifuge separative work capacity. In the next 14 months, key technology demonstrations are expected to lead to an AGC design which can be deployed at GCEP. We are very confident that the AGC will greatly improve the competitive separative work cost position of the United States. Toward this end, the program participants are continuing to work very hard toward the most rapid deployment possible of AGC into GCEP.

Thank you, Madam Chairman.

[The prepared statement of Mr. McWhorter follows:]

Statement of
William C. McWhorter
Program Manager, Advanced Gas Centrifuge
Technical Integrator Program Office
Union Carbide Corporation, Nuclear Division
Before the
Committee on Science and Technology
Subcommittee on Energy Research and Production
U.S. House of Representatives
February 28, 1984

ADVANCED GAS CENTRIFUGE DEVELOPMENT AND DESIGN PROGRAM

Madam Chairman, members of the committee, it is a pleasure for me to be here today and describe the Advanced Gas Centrifuge (AGC) development and design program. The objective of the AGC program is to develop and demonstrate a centrifuge having a separative capacity well above that of the initial Gas Centrifuge Enrichment Plant (GCEP) machine. The initial GCEP centrifuge, the Set III centrifuge, represents a demonstrated technology targeted to be more economical than gaseous diffusion. The AGC is an extension of that technology which will provide centrifuges for use in GCEP which will produce separative work at less than half the cost from existing gaseous diffusion plants.

As requested, I will describe the AGC development program and discuss the schedule for demonstration of this technology, the program funding, and the plans for an early deployment at GCEP.

THE ADVANCED GAS CENTRIFUGE DEVELOPMENT PROGRAM

The development and design program for the AGC is directed toward a target of 600 SWU/yr machine separative capacity as compared to 200 SWU/yr for the initial GCEP centrifuge. This advanced machine, which is designated the Set V (or P3) centrifuge, is being developed by a joint effort involving a team that has many years of experience in centrifuge development and in providing the centrifuges currently being installed at GCEP. This team consists of the AiResearch Manufacturing Company, Boeing Engineering Company, Southeast Inc., Electro-Nucleonics, Inc., Goodyear Aerospace Corporation, the University of Virginia, and the Union Carbide Corporation, Nuclear Division. Union Carbide has been selected by the Department of Energy (DOE) as the technical integrator for AGC development and design.

The improved separative performance targeted for the AGC is achievable by exploiting the capabilities of advanced material which can be used in the construction of the centrifuge rotor. This will permit the operation of the rotor at significantly increased speed, resulting in increased capacity and reduced cost of SWUs. Figure 1 shows a cross section of a typical gas centrifuge with the major machine assemblies shown and the gas flow within the rotor indicated. The AGC design will be essentially the same design and will consist of these basic assemblies but will achieve a much higher separative performance since the separative output of a centrifuge increases very rapidly with an increase in rotor peripheral speed.

Starting with a limited material development and evaluation effort in 1982, dramatic progress has been made to date which confirms the potential for advanced material rotors to operate at speeds sufficient to produce the significantly higher SWU targets of the AGC program. In the past year, material development has progressed from the sample evaluation stage to the fabrication of full-sized rotor tubes. Work to date has indicated that production of these rotor tubes can be accomplished with a consistency and an ease of fabrication comparable to that for rotors of the present Set III centrifuge. At present, full-sized rotor tubes of advanced material have been fabricated by all three of the program participants who currently manufacture Set III rotors. Thus, the major objective of the adaptation of basic Set III manufacturing techniques to the Set V advanced machine has already been successfully accomplished.

In addition, other significant technical achievements have been made. These include the operation of a full-length advanced material rotor at speeds greater than Set III, the qualification of various centrifuge assemblies for operation in prototype AGC tests, and significant demonstrations of the candidate advanced rotor suspension systems.

In the period between now and the end of this fiscal year, AGC rotor tubes will be assembled with other centrifuge components and tested at intermediate speeds which are significantly above the Set III speed to gain important technical data necessary to guide the finalization of the higher-speed AGC design. This information will relate to the rotor and suspension operating characteristics, rotor assembly design, internal gas flow management, thermal control requirements, and the verification of performance models used in centrifuge design and operation.

In late calendar 1984, testing will then begin on centrifuges at full-AGC speed. This will allow the determination of high-speed operating characteristics, validate the performance at full-scale, and provide a demonstrated basis for the GCEP machine design in April of 1985.

Based on information available in April 1985, DOE intends to select either AGC or the Atomic Vapor Laser Isotope Separation Process for demonstration. After that point in time, AGC work would move into the engineering and production phases of the program as shown in the program schedule in Figure 2. Centrifuges of the production prototype design would be used to optimize separative performance during 1986 and, subsequently, a design package would be issued for the production of 30 centrifuges for reliability testing. Also, limited production of additional machines for early deployment in GCEP is being considered.

By 1987, several prototype AGC machines would have been tested for approximately one year and would be expected to be well characterized as to separative performance and operating characteristics. Reliability of the advanced material would have been evaluated in accelerated testing, but full machine reliability testing would have just been initiated. The production and operation of 30 centrifuges to gain both operability and reliability information can be expected to lead to some design advancements and also to an upgrading of the production design package in the 1987-88 time period. The production of Set V machines at a low level and their deployment into GCEP in 1987 would appear to be very attractive in that it would permit an early and orderly shift by the centrifuge manufacturers from production of Set III to production of Set V machines. This would provide for early demonstration and utilization at GCEP of the low-cost separative work technology.

At this point, it is appropriate to mention that the Set V centrifuge will be designed so as to interface with the existing GCEP balance-of-plant equipment with a minimum of required changes. For instance, it is planned that the Set V centrifuge will be of approximately the same height and the same diameter as the present machine and will match the physical interface of the plant operating systems in much the same manner as the Set III. While the Set V centrifuge will very closely resemble the Set III machine in appearance, there will be some plant changes required to provide for the increased capacity of this machine. These are expected to relate principally to provision for increased electrical power, improved mount capability, and to capacity expansion for the feed and withdrawal systems.

I would like now to discuss the impact that additional funding could have on this program, as requested. We believe that the FY 1985 funding that DOE is requesting will allow us to meet the FY 1985 program milestones. Additional funds would provide for increased schedule assurance. This additional funding would permit the parallel pursuit of certain alternate assembly designs in early FY 1985 and would also provide backup test hardware which could prevent delays in the evaluation of the candidate full-speed AGC designs. Specifically, additional funding could be very beneficial in providing a program for a backup rotor suspension system, other hardware for use in principal candidate machine tests, and for material optimization for the specific applications of this program.

In summary, the AGC development and design program is moving aggressively toward the objective of a significantly improved centrifuge for deployment at GCEP. Progress to date has been excellent and has confirmed the potential of advanced material for significantly increasing centrifuge separative work capacity. In the next 14 months, key technology demonstrations are expected to lead to an AGC design which can be deployed at GCEP. We are very confident that the AGC will greatly improve the competitive separative work cost position of the U.S. Toward this end, the program participants are continuing to work very hard toward the most rapid deployment possible of AGC into GCEP.

THE GAS CENTRIFUGE

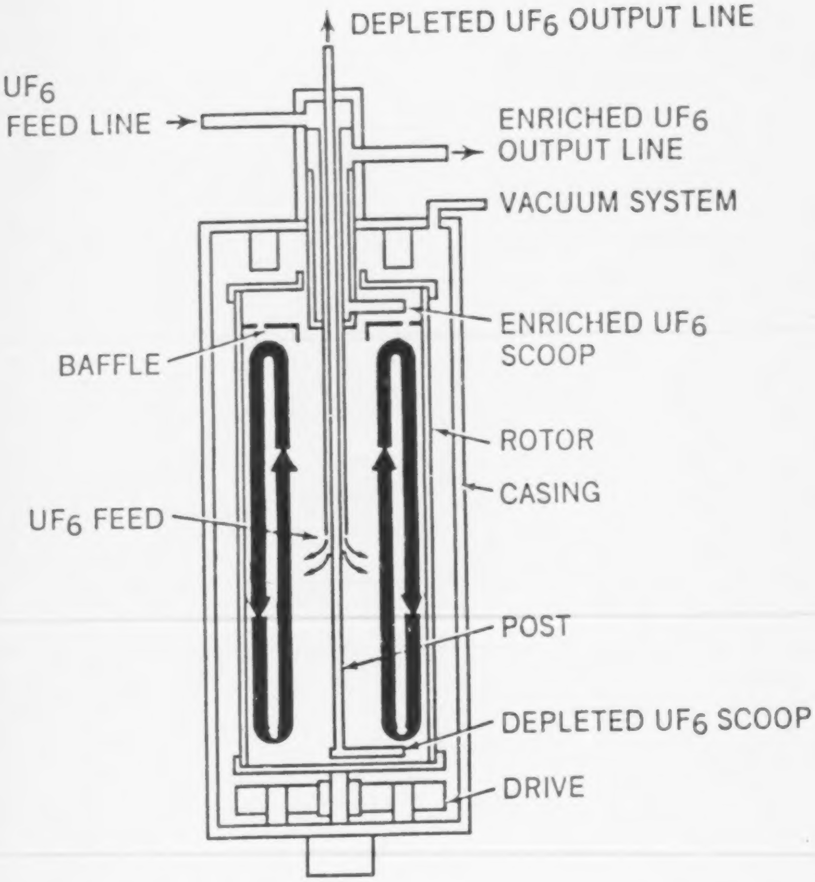

DEPLETED UF6 OUTPUT LINE
UF6 FEED LINE
ENRICHED UF6 OUTPUT LINE
VACUUM SYSTEM
ENRICHED UF6 SCOOP
BAFFLE
ROTOR
CASING
UF6 FEED
POST
DEPLETED UF6 SCOOP
DRIVE

FIGURE 1

PROGRAM SCHEDULES WITH SIGNIFICANT MILESTONES

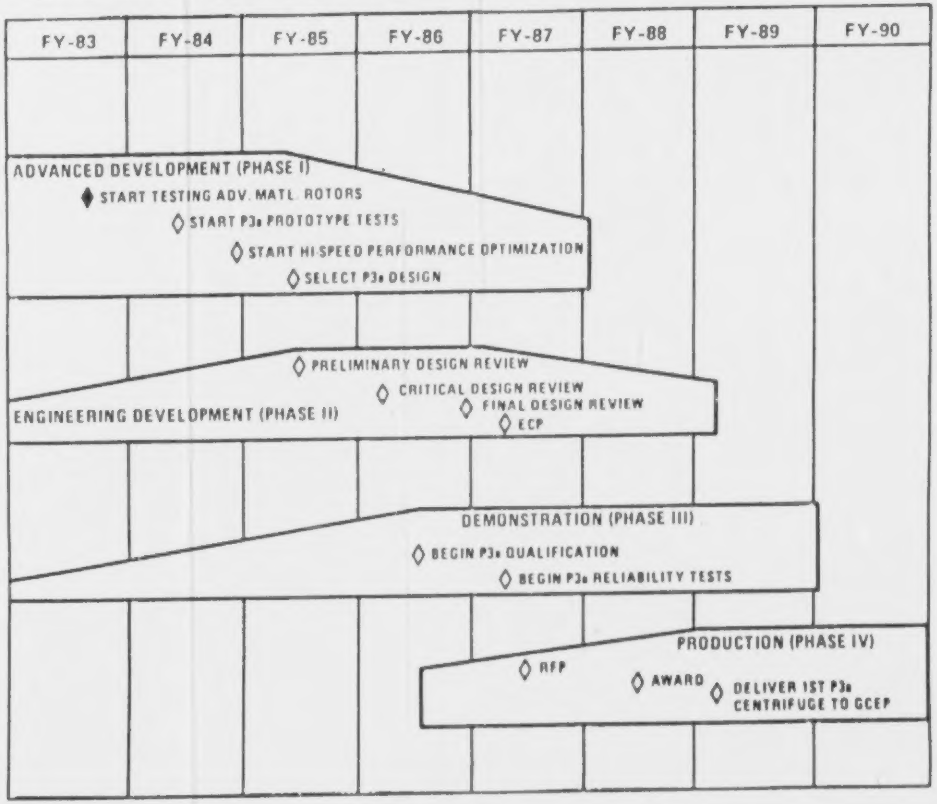


FIGURE 2

Mrs. **Lloyd**. Well, thank you, Mr. McWhorter and Dr. Emmett, and I apologize to you; I had to be out for part of your statement. We kind of wear two or three hats around here and try to make as many committee meetings as possible, and I would apologize to all of you today for lax participation by members. But I think you must understand that most of us have two and three subcommittees going on at the same time at this time of year, when we are preparing to submit our budgetary proposals.

But I understand, Mr. McWhorter, that you could use additional funding productively and it would translate into earlier deployment?

Mr. **McWhorter**. Well, I think the key there is that it is a schedule assurance for early deployment. The funding that is presently proposed is adequate if the concepts which are under evaluation now are successful. The additional funding, which I think was probably correctly characterized in the $5- to $10-million range, could be used for backup hardware and also for the parallel pursuit of certain concepts for alternate centrifuge components.

Mrs. **Lloyd**. That's $10 million total?

Mr. **McWhorter**. Additional, yes. And I might comment that that really is not additional; it partially restores the program plan to its original target value.

Mrs. **Lloyd**. Could you, Dr. Emmett, use more money effectively to translate into an earlier deployment?

Dr. **Emmett**. Yes, indeed. Our situation is that the fiscal year 1985 budget calls for $78 million for AVLIS. Our original budget for that year was going to be about $103 million. We will spend the $78 million almost to zero through the selection in mid-1985, and therefore either have to send everybody off the payroll or to the library to sit for the rest of the year, so the additional $25 million would make a very substantial difference in being able to carry through the remainder of fiscal year 1985 and to continue to collect data which would be keyed to an earlier deployment.

Mrs. **Lloyd**. So your key people will be sort of nonexistent on the job by the middle of next year without additional funding. I think we ought to really look into that at another time, as well, both of you.

I think I'd like to go back now to compare the costs. Dr. Emmett, would you relate to us your projected cost on AVLIS SWU's?

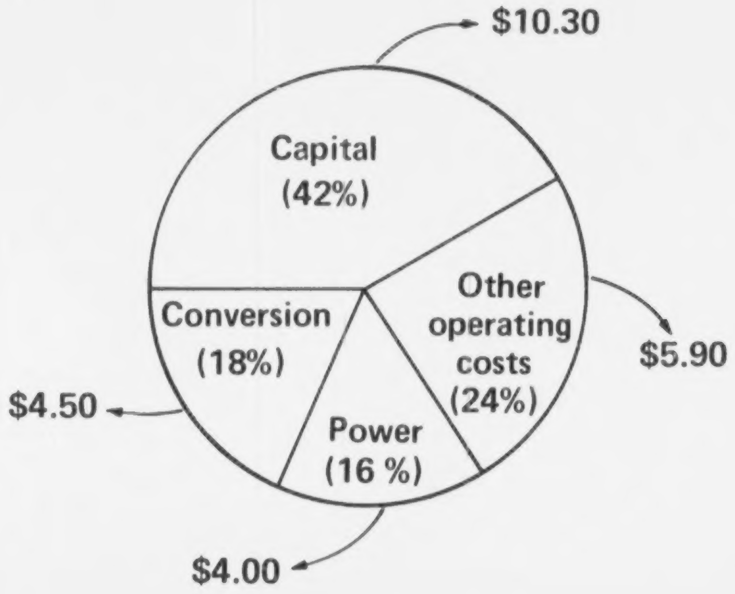
Dr. **Emmett**. Well, there are two cost numbers that are important: the capital cost for building the capability, and the selling price of separative work. What we're talking about is about $100 million per million separative work units of installed capacity for the capital cost.

Mrs. **Lloyd**. Would you repeat that?

Dr. **Emmett**. $100 million per million separative work units per year, capital cost. What we're talking about is the price of feed conversion and separative work, which totals $23 to $25 a separative work unit. That is not an incremental cost; that is a full—you know, amortization, pay the interest rates on the money and amortize the plant and operate the plant. I can show you that specifically here, if I might. (Viewgraph 13.)

Distribution of AVLIS enrichment costs

The distribution of the total cost (~$25/SWU) of enrichment, including all conversion costs, for 1983 process design:



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Viewgraph 13

We're talking about $25 a separative work unit incurred, including the conversion cost of feed; 42 percent of that is interest and amortization on capital, 16 percent is power—$4.50, or 18 percent of the conversion of the feed to metal, and the other operating costs are like $5.90. So, if you want to put this in an incremental sense, as some of the other members have costed, you would just zero this out and the incremental cost would be like $15.

Mrs. LLOYD. Thank you very much.

Mr. McWhorter, does the cost of your advanced machine SWU's include the cost of the set III machines presently planned to be purchased by DOE?

Mr. MCWHORTER. The cost numbers that I keep in mind are based on switching to a set V machine after the completion of half a process building, with set III machines. And under that basis, a general rule of thumb—and there are many ground rules that you can use—but on a go-forward basis, the numbers which I use are around $50 a SWU from that sort of a scenario, given a four or greater building plant. And of course, the greater the number of buildings, the more implementation of set V technology, the lower the SWU range would drop, probably within a range of $40 to $60 a SWU.

Mrs. LLOYD. With four buildings for set V?

Mr. MCWHORTER. Right, with four buildings for set V.

Mrs. LLOYD. Do you all really believe that your respective technologies are going to work at this projected cost? Do you really have backup data to justify your judgment?

Dr. EMMETT. Yes, ma'am, there's no uncertainty that these techniques, set V machines or AVLIS, will enrich uranium. The only uncertainty is cost. I think the analysis of uncertainties that was gone through in the process selection that I showed you, where all of the economic factors and technical uncertainties were factored into the multivariate analysis done by the Union Carbide Corp., is a very adequate and fully bounding representation of cost; that is, I think that the numbers that were developed of a SWU cost bounded by $16 and $33 or $35 is the full range of uncertainty, and I think the plant cost being bounded by $700 million to $1.5 billion for 9 million separative work units is the full bound of the uncertainty there.

Mr. MCWHORTER. The gas centrifuge position, I think, on that question is that we are very confident that the use of an advanced material essentially in a design that has been perfected over a number of years and is based on the technology which has been developed over 20 to 25 years will result in a centrifuge which has considerably improved separative cost advantage to this country. This would allow us in a relatively short period of time, to implement this machine in GCEP and allow us to not only assure that we can be a worldbeater in terms of dollars per SWU, but do it in a near-term timeframe and do it with a great deal of confidence in terms of being able to tell our customers what the future cost of separative work will be.

Mrs. LLOYD. It looks as if DOE will be making a decision about the middle of next year. How would you compare the development stage of each one of your technologies and which one would you say is behind the other by a number of years? How far off are we?

Dr. EMMETT. Well, I think that if both programs are funded on approximately the scale necessary to keep on their schedules, we're talking about deployment in the production sense of the two technologies probably within a year of each other, one way or the other.

Mrs. LLOYD. Mr. McWhorter?

Mr. McWHORTER. I have a viewgraph which is very similar to the one that Dr. Emmett showed.

This viewgraph shows the status of the set V development program at three different points in time, much in the same way as the presentation, I think, that Dr. Emmett gave a few minutes ago. They are mid-fiscal year 1985, mid-fiscal year 1986, and mid-fiscal year 1987. By mid-fiscal year 1985 we will have completed the operation of the intermediate speed machine tests and will have about 6 months of testing on high-speed machine configurations. By that time we will have limited high-speed testing, and in April of 1985 we will have selected a candidate design, which is a go-forward design to be demonstrated in terms of the final set V design. At that time we will have our performance goals validated, our costs bounded reasonably well, our centrifuge lifetime extrapolated, primarily from small-scale experiments and small-scale tests of the materials that we're going to use in this new rotor. By mid-fiscal year 1986 we will have demonstrated high-speed performance and we will have optimized, at high speed, the SWU's coming from the centrifuge that will be the final design. At that time we will have our performance demonstrated, cost information improved by additional information brought about by manufacturing the parts that go into the centrifuge, and having it well characterized in terms of performance. The lifetime still would be extrapolated, but much better information would be available on early operational problems. Typically, in our reliability testing, here we corrected our design problems and early reliability problems very early, and then have had a successful machine in terms of reliability.

In mid-fiscal year 1987 we will have started a multimachine reliability test. We will have multiple machine production experience that will come from having built those machines as well as the many development machines that go into the testing prior to this time. Performance would be demonstrated; cost would be well established for manufacturing, and lifetime data on the machines would be being accumulated.

I hope that this presentation has given you some indication of where the program would stand at those three points in time.

In summary, then, in mid-fiscal year 1985 we expect to have a high level of confidence to go ahead and demonstrate the AGC machine. We will optimize its performance so that in fiscal year 1986 we will have a machine for which the output has been optimized, and we would be in a very confident position then to proceed with a limited deployment at GCEP. In fiscal year 1987, which is the original target date for making the decision to deploy the AGC machine, we would have everything that the program would need to make a very confident decision to be in production in 1989, and to deploy the centrifuges at GCEP.

Mrs. LLOYD. Thank you very much. I thank you gentlemen for your testimony; it has been excellent, and I would ask of you to please submit copies of your viewgraphs to be included in the record, that you have presented. (Attached.)

Thank you for your help today.

[The information follows:]

	STATUS		CUMULATIVE COST FY-84 THRU - ($ M)
MID FY-85	● LIMITED HI-SPEED TESTING ● CANDIDATE SET V SELECTED	● PERFORMANCE GOALS VALIDATED ● COSTS BOUNDED REASONABLY WELL ● LIFETIME EXTRAPOLATED	125
MID FY-86	● HI-SPEED SEPARATION PERFORMANCE DEMONSTRATED	● PERFORMANCE DEMONSTRATED ● COSTS IMPROVED THROUGH ADDITIONAL INFORMATION ● LIFETIME EXTRAPOLATED, BETTER INFORMATION ON EARLY PROBLEMS	190
MID FY-87	● MULTI-MACHINE RELIABILITY TEST STARTED ● MULTIPLE MACHINE PRODUCTION EXPERIENCE	● PERFORMANCE DEMONSTRATED ● COSTS WELL ESTABLISHED THROUGH MANUFACTURING ● LIFETIME DATA BEING ACCUMULATED	265

Mr. McWhorter. Thank you. It was a pleasure to be here.

Mrs. Lloyd. Thank you.

Our next witness is Mr. George Rifakes, who is vice president of the Commonwealth Edison Corp., and he will be accompanied by Mr. Loring Mills, who is vice president for nuclear activities at EEI. We welcome you gentlemen to our committee hearings this morning.

STATEMENT OF GEORGE RIFAKES, VICE PRESIDENT, COMMONWEALTH EDISON CO., REPRESENTING THE EDISON ELECTRIC INSTITUTE, ACCOMPANIED BY LORING MILLS, VICE PRESIDENT FOR NUCLEAR ACTIVITIES, EDISON ELECTRIC INSTITUTE

Mr. Rifakes. Thank you, Madam Chairman.

As you stated, I am George Rifakes, vice president of Commonwealth Edison Co., and I have with me Mr. Loring Mills of the EEI. We are pleased to have the opportunity to appear before you today to discuss the DOE uranium enrichment activities, and the newly offered utility services contract.

Commonwealth Edison currently operates seven nuclear powerplants with a capability of about 6,000 megawatts and have under construction an additional 5 plants with approximately 5,600 megawatts of additional capability. We're currently providing over 40 percent of our customers' needs with nuclear power, and by 1988 we expect this to be about 75 percent. As a consequence of this, we purchase large amounts of enrichment services, currently spending about $135 million a year; and when all the plants are in line, this will about double. We are DOE's largest domestic enrichment services customer, and therefore we have a vital interest in these proceedings. We currently hold 10 long-term contracts. Five of these are requirements contracts covering 10 of our units, and the remainder are adjustable fixed commitment contracts.

Our testimony today is provided on behalf of the Edison Electric Institute, which as you know is the association of investor-owned electric utility companies whose members generate about 76 percent of the electricity produced in the United States. EEI membership includes the vast majority of DOE's domestic uranium enrichment services customers.

Rather than read the full text of the testimony, I would ask that it be adopted for the record and I would like to merely highlight a few of the key points.

Mrs. Lloyd. Without objection, it will be made a part of the record.

Mr. Rifakes. Thank you.

What makes nuclear energy economically desirable is its very low fuel cost compared with the costs of other generation technologies. And an indispensable part of the nuclear fuel cycle is uranium enrichment, as we all know. A reliable source of reasonably priced enrichment is necessary if nuclear energy is to retain its economic advantage.

The current contract situation that we now have with DOE have created some problems in this regard. U.S. utilities who have dealt with DOE have paid relatively high prices for the enrichment services that they have received; and at the same time, because of the lack of flexibility afforded under the AFC contracts, many utilities have been faced with excess inventories which have resulted in additional costs. As a result of these imbalances and relatively high costs, a secondary market in enrichment has developed. Utilities, attempting to mitigate their balances and reduce costs to the ratepayers, have been competing with the Department for customers; and recently many foreign sources have also appeared, and they've captured a large part of the market.

Now, I might say that my company has been one of the companies that's been very active in this secondary market because we are blessed with a requirements-type contract that gives us the flexibility to take advantage of this. The near-term beneficiaries of this activity have been the ratepayers. I am concerned that over the long term, these near-term beneficiaries may be losers because while we're seeing enrichment at lower prices today, we are also eroding DOE's revenues and their ability to come up with the necessary technology in the future to insure that we will have the low-cost enrichment that we require.

Mrs. LLOYD. Your point is well taken.

Mr. RIFAKES. I was pleased that DOE, recognizing both their problem and our problem—which is a responsibility to our ratepayers—initiated meetings with the industry quite some time ago and discussed possible ways where we could resolve these problems on a mutually satisfactory basis. As a result of our many meetings with DOE and other work that they did, they finally produced the utility services contract. The Edison Electric Institute believes that this contract is a reasonable one, and while each utility must make its own decision on whether it converts to the current proposed contract or not, we're encouraging our members to give the contract serious consideration.

The contract provides the utilities assurance of supply, the added flexibility to deal with overstocked inventories, and an opportunity to keep the cost down. At the same time, we believe that DOE can insure the revenues that it needs to maintain services and to permit the continuation of construction and development of the new technology that it's going to require to keep costs down at reasonable levels. The contract gives customers the needed inventory relief, the flexibility, and guaranteed reasonable prices, as I said. But DOE hasn't given the store away; they haven't given unlimited relief to flexibility, and thereby protecting its revenues. And they do have escalation on their prices to protect erosion by inflation in the future.

Now, there are two things that are important here. One is the rate of conversion to the new contract, and ultimately, the rate of retention by DOE of the customers that do convert. And that retention rate, I think, is greatly influenced by DOE's ability to come up with new technologies in the future that will contain the production costs. And therefore there is an undeniable economic rationale for pursuing the development of these newer enrichment technologies. And we're vitally interested in DOE having the most efficient and dependable enrichment technology available to serve our member companies.

DOE is currently investigating two advanced uranium technologies that were discussed here this morning, AGC and AVLIS, and it's difficult for us to know the details of these programs because of the classified nature of the work. Based on what data that has been made available, we believe that AGC is closer to commercialization than AVLIS. And from what we know about the technologies at this point, we also understand that most of the potential of efficiency improvements can be achieved with the AGC technology.

Some comments were made this morning about economics being in the eyes of the beholder. As the final payer of the bills for enrichment, the utility industry is a very interested beholder; and we feel that before DOE finally makes this decision on the technology to pursue and the reasons for pursuing it, we should be given an opportunity to evaluate the plans and to comment on them. In the meantime we support the continuation of GCEP at a reduced level until there's a better understanding of the results of the enrichment contract conversions and an opportunity is provided for a review of the technology choices for improved efficiency in the future.

Again, I'd like to say we support the new DOE contract and we applaud their efforts directed toward recognizing the needs of the consumer.

Thank you for the opportunity to make this statement.

[The prepared statement of Mr. Rifakes follows:]

EDISON ELECTRIC INSTITUTE
TESTIMONY BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
ON THE
DEPARTMENT OF ENERGY URANIUM ENRICHMENT ACTIVITIES

FEBRUARY 28, 1984

Chairman Lloyd and Subcommittee members, I am George Rifakes, Vice President of Commonwealth Edison Company. With me today is Loring E. Mills, Vice President for Nuclear Activities at the Edison Electric Institute. We are pleased to have the opportunity to appear before you today to discuss the Department of Energy's Uranium Enrichment Activities, including the newly offered Utility Services Contract.

Commonwealth Edison Company (CECO) currently operates 7 nuclear power plants (5,929 MWe) and has under construction 5 power plants (5,558 MWe). Currently, CECO provides over 40 percent of its customers' needs from nuclear energy and by 1988 will be relying on nuclear for 75 percent of its generation. In support of these plants, CECO purchases a large amount of enrichment services, spending approximately $135 million per year. We are the Department of Energy's largest domestic enrichment services customer and therefore have a vital interest in the subject of this hearing. CECO holds 10 long-term enrichment contracts with DOE (5 Requirements and 5 Adjustable, Fixed Commitment).

Our testimony is provided on behalf of the Edison Electric Institute, the association of investor-owned electric utility companies whose members generate about 76 percent of the electricity in the United States. EEI membership includes the vast majority of DOE's domestic uranium enrichment services customers.

Chairman Lloyd, about three weeks ago, on February 9th, EEI representatives appeared before you to discuss DOE's nuclear waste program. In their testimony, Messrs. Smith and Draper made a most important point that we cannot overlook. Nuclear energy provided some 13 percent of the nation's electricity during 1983. Nuclear power plants are and will continue to be necessary to provide the electricity to help drive our recovering economy and maintain our economy in the future. Additionally, nuclear power plants have saved billions of dollars for the nations electricity consumers.

What makes nuclear energy economically desirable is its very low fuel cost as compared with other generation technologies. An indispensable part of the nuclear fuel cycle is uranium enrichment. A reliable source of reasonably priced enrichment is necessary for nuclear energy to retain its economic advantage.

Historical Perspective

Uranium in its natural state contains about 0.711 percent of the fissionable isotope U-235. Concentrations of from 2 percent to 4 percent U-235 are necessary for use in a typical light water reactor. The process of increasing the concentration of the isotope U-235 is known as enrichment and is purchased in the form of separative work units (SWU).

The original contracts offered by the U.S. government for enrichment services were market-oriented and permitted customers to purchase the service as and when needed at reasonable prices. These Requirements Contracts, while still in effect for those utilities that hold them, were not offered after December 1972. Beginning in September 1973, the only contracts offered by the government were take or pay arrangements that required the customer to make firm commitments for 10-year periods. These Long-Term, Fixed Commitment contracts were entered into by utilities because there were no alternatives. Many of the contracting utilities soon found that, for reasons beyond their control, they were faced with either holding costly inventories of enriched uranium or paying prohibitive termination charges. In 1975, an attempt was made by the U.S. Government to correct the imbalance between supply and actual demand for enrichment services, and to relieve utilities of some of the financial burdens that were imposed by the Long-Term Fixed Commitment Contracts. Utilities were allowed to make one-time adjustments in their projected needs under their Long-Term Fixed Commitment Contracts at no cost to them during the so-called "open season." Most utilities took advantage of this opportunity, but the relief was short-lived. In May 1978, DOE offered utilities with Long-Term Fixed Commitment Contracts the opportunity to convert to a contract form that allowed some supply flexibility. Even while operating under these Adjustable Fixed Commitment (AFC) Contracts, many utilities were again faced with either large, unneeded inventories or large termination charges.

Current Situation

As a result of the imbalances brought about by changes in utilities' requirements and the relative inflexibility of AFC Contracts, there is a large world surplus of enriched uranium. As a result, holders of enriched uranium and those with surplus commitments for enrichment began to mitigate their costs by becoming sellers in competition with DOE. Price discounting became prevalent and a secondary market developed. Initially, the secondary market participants in the U.S. were trading DOE-produced material. Now there are also significant purchases from foreign sources, which not only erode DOE's position as a supplier, but also have negative impacts on our trade balances.

While DOE had a virtual monopoly on enrichment services ten short years ago, its share of the market has dropped significantly. About one-half of DOE's current enrichment sales are made under contracts that permit terminations such that customers can purchase SWUs elsewhere. The result is that one-half of DOE's business has the potential of being cancelled. In fact, DOE is losing about 19 percent of its anticipated commercial sales in FY 1984.

DOE must, by law, operate the enrichment program on a full cost recovery basis. As it loses business it must spread its costs over a shrinking base of customers. The net result is potential, large price increases and the loss of more customers; a vicious cycle.

Furthermore, by Office of Management and Budget requirements, expenditures must be fully covered by SWU sales revenues in each Fiscal Year. DOE's yearly pricing calculation, however, cannot explicitly include future construction and development costs.

Therefore, the cash required to pay for future technology construction and development is generated by including in the price such accounting items as depreciation and imputed interest.

DOE has been faced with conflicting objectives. On the one hand, it must meet its statutory mandate to recover all costs over a reasonable period of time coupled with the Administration's stricture to avoid a net appropriation request in any one year. This objective tends to move DOE towards higher prices and a need to guarantee its sales through reduced customer flexibility, which would drive away customers and fuel the secondary market. On the other hand, in order to hold or expand its market share, DOE must bring its prices in line with its competition and offer relief to its customers who hold large SWU inventories. This objective tends to move DOE towards lower prices and greater flexibility, which may reduce revenue and lead to cuts in the DOE advanced technology programs that are necessary to develop the capability to bring down enrichment costs over the long-run.

New Contracting Initiatives

Recognizing the dilemma, in early 1982, DOE began a review of its most current contracts and held discussions with its customers. Two draft contracts were also published and customer comment was actively solicited. The input form the customers has been consistent: DOE must develop a contract that recognizes the effects of the current oversupply of enrichment services. If a new contract was not developed that would allow a controlled balancing of supply and demand, strong market forces would do so in an uncontrolled manner with the potential of further damage to DOE as a reliable low cost supplier.

In response to the requests of its customers and the growing pressure from the secondary market, DOE developed a contract that represents a fair compromise between the customers' needs and DOE's constraints.

The Utility Services Contract

The Edison Electric Institute believes that the newly announced Utility Services (US) uranium enrichment contract is a reasonable contract and, while each utility must make its own decision on conversion from its current contracts, we are encouraging our members to give the US contract serious consideration. The US contract provides the utilities assurance of supply, added flexibility to deal with over-stocked inventories, and an opportunity to keep cost to ratepayers reasonable. Under the Contract, DOE can insure the revenues it needs to maintain services and to permit the continuation of construction and development of new technology at reasonable levels. We applaud DOE for its efforts and believe that it has properly addressed the issue.

We are pleased to note that on February 6, 1984, Duke Power Company, one of DOE's largest customers, was the first customer to execute a conversion to the new US contract. Furthermore, four other DOE customers have indicated their intent to convert to the new contract. We expect that most domestic utilities will convert to the new contract. The US contract appears to have accomplished a reasonable compromise of the conflicting objectives mentioned earlier. The US contract gives customers needed inventory relief, flexibility, and guaranteed reasonable prices. DOE has not granted unlimited relief and flexibility, thereby protecting its revenues, and its price will escalate on a fair and reasonable basis assuring that DOE will meet its cost recovery statutory obligations. We are very encouraged by our perceptions of the effect of the US contract on both DOE and its customers.

The Future of the DOE Uranium Enrichment Program

It is extremely important that the United States have a strong uranium enrichment program to support the current and future operation of the nation's nuclear power plants and to help support the nations nuclear non-proliferation goals. To say that the DOE uranium enrichment program should not progress to more economic and efficient technologies, because the current facilities possess sufficient capacity, would be short-sighted, indeed. DOE must bring on future technology to contain the ever-rising cost of uranium enrichment. If it does not, greater numbers of current customers will find refuge in the secondary market and, eventually, in the foreign producers, who can, due to their pricing procedures, national energy policies, and foreign exchange rates, underprice DOE in today's market. As we stated earlier, loss of market will force up DOE's prices causing more market loss. However, there isn't enough capacity in the foreign producers' facilities at this time to fill our domestic demand. Consequently, a significant portion of United States ratepayers would be forced to pay higher charges because many electric utilities would be forced to purchase the very costly DOE SWUs. While under the new US contract these effects are lessened considerably due to the manner in which the contract guarantees DOE a portion of the market, the rate of retention by DOE of its customers, however, will be greatly influenced by DOE's dedication to a program of future development that will contain its production costs. Therefore, there is an undeniable economic rational for pursuing development of newer enrichment technologies.

The DOE FY 1985 Budget Request documents indicate that the size and scope of DOE's new enrichment technology program will be driven by the market response to the new contract and attendant revenues. We endorse this approach and eagerly await the outcome of the contract conversions and DOE's definition of the future progam. Since the new contracts have only been available for about one and one-half months, and customers have until the end of September to convert to the new Contract, it is too early for DOE to determine the revenues that will be available to it during Fiscal Year 1985. However, in the Budget Request documents, DOE indicates what its program will be during this interim period while it awaits the effects of its new contract offer. We can, therefore, offer some comments at this time.

Funds for Future Development

We are vitally interested in having the most efficient and dependable enriching technology available to serve our member companies. Using DOE's ten-year cost recovery pricing methodology, the government will recover its costs, as required, for any future construction and development program. It appears, however, that DOE may not have the year-to-year cash flow necessary to avoid net appropriations in each Fiscal Year. DOE has indentified, in its Budget Request, the need to find alternative sources of financing to continue the work necessary to insure the timely availability of lower cost future technology. We are aware of the problem and are waiting to see what proposals DOE will make. Some innovative opportunities for financing the development of the new technologies may be necessary and we want to help DOE develop them.

While external financing is one means to assuring the availability of funds for future construction and development, there may be other sources of cash within the DOE enrichment program that should be fully explored now. DOE should vigorously explore cost reduction alternatives, including the reduction or elimination of demand charges for energy not taken and the retirement of facilities not necessary to meet its contract obligations. We also look forward to helping DOE explore ways to economize within the enrichment enterprise.

Selection of Future Technology

DOE is currently investigating two advanced uranium enrichment technologies: Advanced Gas Centrifuge (AGC) and Atomic Vapor Laser Isotope Separation (AVLIS). It is difficult for us to know the details of these programs, because of the classified nature of the work. However, based on what data has been made available, we are aware that AGC is closer to commercialization than AVLIS. From what we know about the technologies at this point, we also understand that most if not all of the potential efficiency improvements can be achieved with AGC technology.

DOE has indicated that it will make a technology choice in mid-FY 1985. It is currently developing a plan for making this determination. Our vital interest in this decision compels us to request an opportunity to participate in the process. We want the choice to be made in a manner consistent with the best interests of those to be served by the decision -- the electric ratepayer.

When DOE proposed its future operating program details and its program for developing more efficient capability, we will want the opportunity to evaluate the plans and comment on them. In the meantime, we support the continuation of the Gas Centrifuge Enrichment Plant (GCEP) at a reduced level until a better understanding is provided on the results of enrichment contract conversions and an opportunity is provided for the review of the technology choices for improved efficiency.

Conclusion

It is clear that DOE is responding to its customers and taking some bold steps to improve its market position, lower future costs and remain a reliable supplier of enrichment services. DOE, through its new US contract offer has made a commitment that recognizes th industry's needs. We applaud and support the recent DOE efforts. We fully support the need for the United States to continue to be a major supplier of enrichment services to meet the world needs and to do so on a basis that provides an assured long-term supply capability at the lowest reasonable cost. This is not only in the best interest of the nuclear utilities and their customers, but because of the effect on our foreign trade balance and in meeting our non-proliferation goals, of the nation as a whole.

* * * *

Mrs. LLOYD. Well, thank you very much for your very supportive statement.

What would you do differently in DOE's fiscal year 1985 budget proposal if you had the option to change it? Is there any specific proposal that you'd like to make?

Mr. RIFAKES. No, I don't believe so.

Mrs. LLOYD. I appreciate that you touched on the subject that if DOE's customers continue to find alternative suppliers, that it is going to have a major impact on our enrichment business and it's going to really leave someone way out in left field down the road if we can't see to really take into consideration the impact of this decision.

Do you basically feel the new contract will be well received by DOE's customers?

Mr. RIFAKES. Yes.

Mrs. LLOYD. Do you think the enrichment enterprise ought to be funded using a revolving fund, revolving authority?

Mr. RIFAKES. Yes.

Mrs. LLOYD. Would you elaborate on that?

Mr. RIFAKES. Well, the pay-as-you-go plan has imposed severe restrictions on the ability of DOE to move programs along. Most enterprises have borrowing authority; they capitalize costs and spread them over future business, over the beneficiaries of the development. And it's appropriate that in an enterprise of this sort, the same thing should be done.

Mrs. LLOYD. Well, would you favor adding more funds for the advanced technologies?

Mr. RIFAKES. Adding more funds——

Mrs. LLOYD. To speed up the R&D development work for the advanced technologies, to insure more confidence?

Mr. RIFAKES. I favor that, depending on what it would do to the near-term price; that is, if we could add more funds by going out and financing and not having the zero sum recovery, so that the impact on near-term price would not be adverse, clearly we'd favor it. Electric rates are already high enough.

Mrs. LLOYD. I think that most people would agree with that statement.

Do you have a position on the privatization of the enrichment business? Mr. Mills? Either one of you?

Mr. RIFAKES. I can speak for Commonwealth Edison on this thing. Over the years we've taken the position that a venture like enrichment is better operated by a quasi-governmental corporation, much like TVA, with borrowing authority and outside of the budget process so that it can be run more like a business than ventures of this type seem to be run by the Congress. So we'd favor it to that extent.

Mr. MILLS. If I may comment on that, Chairman Lloyd, we have looked at the privatization question of enrichment a number of times over the last decade. While it appears attractive under some arrangements, we have not found a mechanism that makes it appear to work. The competitive situation that exists in the world today on uranium enrichment does not favor a need for additional capacity. It does favor a need for more efficient capacity, and the mechanism for providing this more efficient capacity within the regulatory environment in which we leave on the nuclear side, we believe it can best be done with some kind of a quasi-Federal—but a very important Federal—arrangement. Whether there can be a private element of it is still an unknown. We have not found a way to do that.

Mrs. LLOYD. Well, thank you very much. I think you answered all of my questions that I really had to ask you in your statements; it was well done. And for the record, all of the written statements that were presented to the subcommittee today will be made a part of the record at the appropriate point.

Again, thank all of you for participating and those that are witnesses for the hearing. And if there are no further comments, the subcommittee stands adjourned.

[Whereupon, at 11:07 a.m., the subcommittee recessed, to reconvene at the call of the Chair.]

1985 DEPARTMENT OF ENERGY AUTHORIZATION

WEDNESDAY, MARCH 7, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
Washington, D.C.

The subcommittee met, pursuant to notice, at 1 p.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd (chairwoman of the subcommittee) presiding.

Present: Representatives Lloyd and Walker.

Staff present: Keith Jansen, technical consultant; William Harvey, minority energy coordinator; and David Clement, minority counsel.

Mrs. Lloyd. The subcommittee will come to order.

Good afternoon, ladies and gentlemen. Today we will be receiving testimony from Government and private witnesses on the Department of Energy's fiscal year 1985 budget request for research and development in electric energy systems, energy storage systems, and small-scale hydroelectric systems.

Modern society has been the beneficiary of a host of technological advances unprecedented in the history of mankind. This Nation's preeminence in the technical revolution is a direct reflection of our historical commitment to developing and maintaining a strong and viable scientific and technical community. A vigorous program of research and development has been the medium through which we have made these achievements, thereby fueling our growth and enhancing our economic welfare.

In this light, our specific concern today focuses on the Government's role in funding and conducting the appropriate level of high-risk, long-term R&D activities in these programs. It is our intent that these activities be in the national interest because support for such R&D in the private sector is precluded by economic or other factors.

Effective long-term R&D of this nature requires a consistent level of funding and activity. It has become increasingly more difficult in recent years to sustain these critical programs in the face of budgetary restraints and pressing Administration efforts to severely limit such R&D activities. We must be very judicious in setting the priorities for these programs.

While much has been accomplished, there remains a significant amount of work that must be continued if we are to realize the full value of our investments thus far. The small-scale hydroelectric program, which has been funded since 1977 with approximately $70 million, is in the monitoring and technical transfer phase. Electric energy systems will emphasize research on the biological health effects of high-voltage electric fields, the effects of an electromagnetic pulse on the electric grid, and improving the efficiency of electric energy delivery systems. The energy storage program research effort will address the development of efficient, cost-effective technologies to store energy from various sources for use in electric vehicles, utility load leveling, alternative fuel generation, and solar-wind conversion. Successful advanced storage systems will result in petroleum savings, create major new industries, and reduce the balance of payments. We certainly look forward to hearing what our witnesses have to say about these and other related subjects today.

Before we begin receiving testimony, I would like to call upon the minority staff to see if our ranking Republican member would care to make a statement as well.

Minority staff. Both Mr. Winn and Mr. Walker.

Mrs. Lloyd. Both Mr. Winn and Mr. Walker would like to have their statements included in the record at this point, and, without objection, they will be included in the record.

[The opening statements of Mr. Winn and Mr. Walker follow:]

OPENING STATEMENT BY THE
HONORABLE LARRY WINN, JR.

ENERGY RESEARCH AND PRODUCTION SUBCOMMITTEE
HEARING ON ELECTRIC ENERGY SYSTEMS, ENERGY STORAGE SYSTEMS, AND SMALL-SCALE HYDROELECTRIC SYSTEMS
MARCH 7, 1984

THANK YOU, MADAM CHAIRMAN, FOR THIS OPPORTUNITY TO WELCOME WITNESSES FROM THE U.S. DEPARTMENT OF ENERGY, OUR NATIONAL LABORATORIES, AND VARIOUS ENTITIES OUTSIDE GOVERNMENT. WE HAVE A DIVERSE AND INTERESTING GROUP OF PROGRAMS TO DISCUSS TODAY AND I AM CERTAIN WE WILL FIND THE TESTIMONY BENEFICIAL.

A REVIEW OF THE BUDGET REVEALS THAT THE DEPARTMENT OF ENERGY'S REQUEST APPEARS TO PROVIDE THE CORRECT PRIORITIES TO THESE SEVERAL PROGRAMS. FOR EXAMPLE, A MINIMAL AMOUNT OF FUNDS ARE REQUESTED FOR THE SMALL-SCALE HYDROELECTRIC PROGRAM. DUE TO THE ESTABLISHED NATURE OF THE GENERATING PROCESS, THIS IS CERTAINLY FITTING AND PROPER. ON THE OTHER HAND, THERE IS A SIGNIFICANT AMOUNT OF FUNDING REQUESTED FOR BATTERY STORAGE. WE THINK OF BATTERY STORAGE AS A MATURE PROCESS, BUT WE SEE A NUMBER OF INTERESTING CONCEPTS BEING EXPLORED IN THIS PROGRAM. I BELIEVE THE FUNDS REQUESTED BY DOE ARE TOTALLY ADEQUATE TO MEET THE SCOPE OF THE PROGRAMS THEY HAVE OUTLINED.

A VERY SIGNIFICANT FEATURE OF ALL THESE PROGRAMS IS THAT DOE IS WORKING CLOSELY WITH INDUSTRY. ALTHOUGH WE HAVE NOT BEEN PROVIDED THE DETAILS, IT IS HOPED THAT SUCH IS THE CASE IN ALL OF THE PROGRAMS BEING CONSIDERED TODAY. AS I HAVE MENTIONED IN THE PAST, WE HAVE BEEN TOLD REPEATEDLY THAT THE MOST SUCCESSFUL EXAMPLES OF TECHNOLOGY TRANSFER HAVE OCCURRED WHEN THE PROGRAMS INVOLVE INDUSTRY IN THE EARLY PLANNING STAGES, THROUGH TO PROGRAM INITIATION AND COMPLETION. WE THEREFORE HOPE TO HEAR THAT THE DISCOVERIES FROM THESE PROGRAMS ARE FINDING THEIR WAY INTO INDUSTRY AND PROPER APPLICATIONS IN A TIMELY AND EFFICIENT MANNER. WE ALSO HOPE TO HEAR THAT BECAUSE OF INDUSTRY'S INVOLVEMENT, AND IN SOME CASES, NEAR-TERM COMMERCIALIZATION, INDUSTRY IS SHARING IN THE COST OF THESE PROGRAMS.

MADAM CHAIRMAN, I BELIEVE THIS HEARING WILL BE VERY HELPFUL AS WE CONTINUE TO CONSIDER THE DOE FY 1985 AUTHORIZATION REQUEST.

THANK YOU.

OPENING REMARKS OF
REPRESENTATIVE ROBERT S. WALKER

MARCH 7, 1984

GOOD AFTERNOON, MADAME CHAIRMAN, AND I WOULD LIKE TO JOIN YOU IN WELCOMING OUR WITNESSES HERE BEFORE THE SUBCOMMITTEE TODAY.

WE ARE NOW RAPIDLY APPROACHING THE END OF OUR ANNUAL BUDGET HEARING SCHEDULE AND WE WILL BE MARKING UP OUR PORTION OF THE DEPARTMENT OF ENERGY AUTHORIZATION BILL NEXT WEEK. THE PURPOSE OF THESE HEARINGS EACH YEAR IS TO EXAMINE THE BUDGET PROPOSED BY THE PRESIDENT AND TO COMPARE IT WITH WHAT WE SEE AS OUR NATIONAL RESEARCH AND DEVELOPMENT NEEDS.

TODAY WE WILL BE LOOKING AT OUR EFFORTS IN THE AREAS OF ELECTRIC ENERGY SYSTEMS, ENERGY STORAGE SYSTEMS AND SMALL-SCALE HYDROELECTRIC SYSTEMS. THESE ARE ALL AREAS OF HIGH IMPORTANCE IN AN ERA OF WORLD ENERGY SHORTAGES AND AN UNCERTAIN ENERGY FUTURE.

I WOULD LIKE TO SAY TO THE CHAIRMAN, AND ALSO TO OUR FIRST WITNESS, ENERGY UNDERSECRETARY PAT COLLINS, THAT, IN GENERAL, IT APPEARS TO ME THAT THERE IS SUFFICIENT FUNDING IN THE PRESIDENT'S BUDGET REQUEST THIS YEAR TO ACCOMPLISH A FULL AND VALUABLE PROGRAM OF ENERGY R&D IN

ALL OF THE AREAS UNDER OUR JURISDICTION. IT DOES APPEAR TO ME THAT THERE ARE A NUMBER OF ADJUSTMENTS WHICH WILL HAVE TO BE MADE IN THE WAY THE BUDGET IS STRUCTURED.

AS AN EXAMPLE, MADAME CHAIRMAN, I WOULD POINT OUT THE INITIATIVE TO DEVELOP A NEW GENERATION OF MODULAR INHERENTLY SAFE REACTORS. WE HAVE DONE A GREAT DEAL OF TALKING ABOUT THIS CONCEPT THROUGHOUT OUR HEARINGS THIS YEAR, AND THE RESPONSE HAS BEEN NOTHING SHORT OF SPECTACULAR. VIRTUALLY EVERY WITNESS BEFORE THE COMMITTEE HAS BEEN STRONGLY SUPPORTIVE OF THE CONCEPT, AND IT SEEMS OBVIOUS TO ME THAT IT IS A NEW DIRECTION WHICH IS NEEDED IN THE NUCLEAR INDUSTRY.

WE HAVE ALSO DISCUSSED THE NEEDS TO RE-DIRECT A NUMBER OF OTHER PROGRAMS WITHIN THE DEPARTMENT, AND I THINK THAT MEMBERS ON THIS SIDE OF THE AISLE WILL BE SUPPORTIVE OF THOSE IDEAS. WHAT WE WILL BE LOOKING FOR, MADAME CHAIRMAN, IS A WAY TO ADDRESS THESE NEEDS WITHIN THE BUDGET REQUEST. AS YOU KNOW, THERE IS A STRONG, AND GROWING BELIEF WITHIN THE CONGRESS, AND WITHIN THE POPULATION, THAT WE MUST REGAIN CONTROL OF RUNAWAY SPENDING. I EXPECT THAT THE MINORITY MEMBERS OF THIS COMMITTEE WILL BE WILLING TO WORK WITH YOU, MADAME CHAIRMAN, TO FIND AGREEMENT ON PROGRAM DIRECTION ALONG THE LINES OF OUR DISCUSSIONS DURING THE HEARINGS THIS YEAR, BUT I ALSO EXPECT THAT WE WILL BE FORCED TO RESIST ANY ADD-ONS ABOVE THE BUDGET LEVEL.

TO OUR WITNESSES I WOULD SAY THAT THESE COMMENTS DO NOT REFLECT ANY

LACK OF COMMITMENT TO YOUR INDIVIDUAL PROGRAMS. IN FACT, WE STRONGLY SUPPORT WHAT YOU ARE DOING. BUT, JUST AS EACH OF YOU MUST LIVE WITHIN A FAMILY BUDGET WHERE YOUR EXPENDITURES CANNOT EXCEED YOUR INCOME, AND JUST AS YOU CANNOT CONTINUE IN THE BUSINESS WORLD FOR LONG WHEN THE BOTTOM LINE IS IN THE RED, THE TIME HAS COME FOR THOSE OF US HERE IN CONGRESS TO REALIZE THAT WE CANNOT CONTINUE OUR COURSE OF DEFICIT SPENDING. THE ECONOMY IS RAPIDLY IMPROVING, BUT UNLESS WE GET THE DEFICITS UNDER CONTROL IMMEDIATELY WE MAY SEE A QUICK RETURN TO THE PROBLEMS OF THE PAST.

IN CONCLUSION, MADAME CHAIRMAN, I SEE WHAT WE ARE DOING HERE TODAY AS ONE OF THE MOST IMPORTANT DUTIES OUR CONSTITUENTS ELECTED US TO CONGRESS TO CARRY OUT. THESE HEARINGS GIVE US THE OPPORTUNITY TO EXAMINE PROGRAMS, EVALUATE THEIR EFFECTIVENESS, AND WEIGH THEM AGAINST COMPETING PRIORITIES, AND FINALLY, GIVE US ALL OF THE NECESSARY INFORMATION TO MAKE SOUND PUBLIC POLICY AND ALLOCATE OUR INCREASINGLY SCARCE FINANCIAL RESOURCES.

THANK YOU, MADAME CHAIRMAN.

Mrs. LLOYD. We also ask unanimous consent that statements of Congressman Oberstar and Mr. Dougherty be made a part of the record also.

[The prepared statements of Congressman Oberstar and Mr. Dougherty follow:]

STATEMENT OF THE HONORABLE JAMES L. OBERSTAR

OF MINNESOTA

BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

SEASONAL ENERGY STORAGE SYSTEMS

MARCH 7, 1984

MR. OBERSTAR. MADAM CHAIRWOMAN,

The challenge of lessening our dependence on foreign traditional exhaustable energy sources involves not only developing alternative energy sources, but finding new ways to use existing energy supplies more efficiently. Seasonal energy storage is one such technology; it allows us to recoup heat and chill loss.

Heat and chill sources are usually out of phase with consumption demand. Cogenerated heat from fossil or nuclear powerplants, for example, is available on a year round basis. Waste heat from trash burning comes in bursts. Solar heat and winter chill are available when they are not needed. Seasonal storage evens out these differernces. Heat energy can be stored in aquifers, in tanks, and in the soil. With seasonal storage we can trap heat and chill and apply it when and where it is needed, thus reducing the problems of peak energy use during seasons of high demand.

Seasonal energy storage can also aid warmer areas of our country through chill storage. This method consists of pumping water from an aquifer into a cooling tower where it is chilled and injected into a second well. In the summer, the cold water is withdrawn and used for air conditioning. Since 1965, China has applied this technology successfully in ten cities.

Seasonal energy storage is also being successfully developed in the United States. At the University of Alabama, winter chill is stored in an aquifer for use during the summer. This project will evaluate the technical and economic feasibility of providing stored chill in the summer for cooling, a project similar to that successfully developed in China. At the University of Minnesota, storage of superheated water in deep aquifers is being explored. The Illinois Department of Energy and Natural Resources is currently developing a project on the use of pond ice to cool state-owned buildings.

In my own district, in Ely, Minnesota, seasonal energy storage is being studied in abandoned mines. Here, in one of the coldest parts of the U.S., heated water stored in a mine is pumped out, and distributed. Its temperature is increased by heat pumps. This heat is then used in a district heating system. The Department of Energy has provided a relatively small amount of its seasonal storage budget for this project - about $50,000 over a two year period - but this funding was crucial to leverage state and private support of about $200,000, to keep the project viable. And yes: DOE has concluded that mine water and heat pumps could indeed provide the heat the town needs.

Other experimental facilities in Boston and Alabama also depend on federal dollars to promote state and private investments. Seasonal energy storage has been proposed for Alaska and the Virgin Islands. Public support for and involvement in seasonal energy storage is crucial for many reasons. Often this technology utilizes a public resource, such as an aquifer, which requires public involvement to insure responsible use. States usually have limited funds for these projects. Private investors can rarely recapture large research and development expenditures in highly specialized hardware; and they are hesitant to take the large technical risk involved in seasonal storage research. But as we have seen in Ely, Minnesota, a small public appropriation can spur greater private involvement.

The Department of Energy has spent some 12 million dollars in the past six years on research in the field of seasonal energy storage programs. With an additional $2 million for seasonal storage under the Division of Energy Storage, representing level funding, we can continue our research in Alabama, Massachusetts, Minnesota and other states.

Seasonal storage could form an important and viable component of a national energy program but research and experimentation is yet needed. Unfortunately, the pace of American research to seasonal storage has been slowing down in the last few years. And now it threatens to come to a complete standstill.

Meanwhile, the rest of the world has been forging ahead with seasonal storage. Sweden has many operating facilities; Switzerland and Denmark are developing experimental sites. France is planning to use extensive aquifer heat storage for its many nuclear power plants. In a few years, the United States may be in the embarassing position of having to import seasonal energy storage technology from abroad in spite of having been at one time the acknowledged pioneer of the process.

I have also included in my testimony letters of support for seasonal storage programs from the New York State Energy Research and Development Authority and the International District Heating Association.

I urge the Subcommittee to continue these important energy research programs.

INTERNATIONAL DISTRICT HEATING

ASSOCIATION

1735 EYE ST. N.W. SUITE 611
WASHINGTON, D.C. 20006
202/223-2922

March 2, 1984

The Honorable Marilyn Lloyd Boquard
The United states House of Representativs
2334 Rayburn House Office Building
Washington, D.C. 20515

Dear Ms. Boquard:

In your position as Chairwoman of the Subcommittee on Energy Development and Applications may I respectfully urge you to favorably consider legislation in regardd to seasonal energy stroage. The International District Heating Association (IDHA) is a 75 year old association that represented the industry as it built systems in most major U.S. cities, than saw most of them fall into holding patterns during a period when there was little regard being given to the savings of fuels, conservation of water, or protection of air quality. Now these are terribly important issues, and we find that district heating and cooling is staging a substantial return to popularity.

Not only is district heating and cooling (DHC) important in the conservation of fuels and water, but it has important social impacts. Reasonably priced heating and cooling systems can stabilize our urban areas. Installation of DHC systems can provide substantial employment and it means jobs in the areas where the need is most critical. The skills are relatively simple and transferable to most types of construction. DHC is steel intensive, pipe, valves, boilers and fittings--certainly the steel industry needs our help.

District heating and cooling is limited if we cannot provide some storage of thermal energy. Rejection of heat from power plants is greatest during summer months when comfort heating is at its lowest demand. Conversely, summer cooling capabilities can be economicaly produced during the winter seasons. We know this can be done, but there is research and development necessary to bring thermal storage to the status of technology that is available to even modest size communities.

DHC with effective storage could save U.S. consumers an estimated $14 to $28 billion annually by the year 2000 based on oil prices of about $30 per barrel. This is important to every citizen of the U.S.

Sincerely,

Norman R. Taylor

Norman R. Taylor

New York State
Energy Research and Development Authority
Two Rockefeller Plaza • Albany, New York 12223
(518) 465-6251

WILLIAM D. COTTER
Chairman

IRVIN L. WHITE
President

February 29, 1984

The Honorable Marilyn Lloyd Bouguard
Chairman Authroization Committee

Dear Ms. Bougard:

I would like to express my opinion as to the importance of long-term thermal energy storage concepts to our energy future and specifically the need for continued federal support of these programs.

There are a host of potential applications for long-term or seasonal thermal energy storage (STES) ranging from improving the utilization of cogeneration and waste heat (which nearly always suffer from temporal mismatches between supply and demand) to storage of winter chill for summer air-conditioning. Since the value density of the stored energy is low, a very cheap storage means must be used to make the system cost effective. A number of promising possibilities have emerged, such as piles of winter frozen ice and the utilization of several structures such as earth, rock caverns, and most notably, aquifers. Analysis, as well as some limited experience, has indicated that at least some of these storage systems are technically and economically feasible.

There are a number of compelling reasons for public support and involvement in many of these STES concepts. First STES often utilizes a major public resource, such as aquifer, which requires public involvement to insure responsible use. Second, the scale of the projects is necessarily large. Third, there is a minimal possibility for a private investor to recapture R&D expenditure in STES by establishing a proprietary position. Most STES concepts involve large expenses for things like drilling services, heat exchangers, and piping but little specialized proprietary hardware or service. Finally, there is so much technical risk that no one in the private sector is willing to implement most STES technologies at this time. I am especially aware of the last point since I have spent much time trying to start an aquifer chill storage project in New York State, using a modest amount of State money as an inducement to private investment, with no success to date. We do, however, have a couple of prospects which could result in really interesting projects if we could get an adequate cooperative funding package together.

The principal criterion of the administration's energy funding philosophy seems to be technical risk. Aquifer storage fully qualified in this respect. Some of the other STES concepts also have serious technical risk, or other special reasons, which make the private sector unwilling to develop them. Nevertheless, there is a compelling body of data suggesting the ultimate virtue of STES systems. Therefore, I am firmly convinced of a need for public involvement in supporting R&D at this time.

We in New York State are conducting limited work on naturally frozen ice storage and use. Other states do not even have our level of effort. I personally strongly believe STES is exactly the kind of thing the public sector should support and I urge you to give careful consideration to future federal funding for these programs.

Sincerely,

Gunnar E. Walmet

Gunnar E. Walmet
Program Manager

STATEMENT OF JOHN J. DOUGHERTY
VICE PRESIDENT, ELECTRICAL SYSTEMS DIVISION
ELECTRIC POWER RESEARCH INSTITUTE
to the
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
March 7, 1984

Mr. Chairman and Members of the Subcommittee:

My name is John J. Dougherty, Vice President of the Electrical Systems Division for the Electric Power Research Institute (EPRI). On behalf of EPRI, I would like to thank you for the opportunity to present to this Committee a statement outlining my views of the need for a continuing involvement of the Department of Energy (DOE) in research and development in the field of electric energy systems. A strong interconnection of the many power systems in the U.S. is a national necessity, given the critical importance of a reliable supply of electrical energy. Most of DOE's Electric Energy Systems program is dedicated to this need.

The Electric Energy Systems Division of DOE has a long history of close cooperation with the electric power industry that actually precedes the formation of the Department. It began with a group formed under F. F. Parry in the Department of Interior about 1970. Later that embryo group became a division under the Energy Research and Development Administration (ERDA) and was expanded somewhat. Finally it became a part of the present organization when DOE was formed in 1977.

At the peak of its activity in 1978 and 1979 the Electric Energy Systems Division was staffed by 38 people. At that time it had a budget and a staff somewhat comparable to the Electrical Systems Division at EPRI. A close working relationship between the two groups was established by Mr. F. F. Parry and me and this relationship has continued under the direction of the present Director, Ray Dunlop. While our assigned priorities and goals are frequently different, our general modus operandi has been to carry out complementary programs and to monitor each other's programs and future plans so that the needs of the nation in this particular area of technology are well served at a minimum overall cost.

Efforts are continuing to maintain this close knit relationship but it is difficult when the staff of the Electric Energy Systems group at DOE has been reduced to five people. Of course the headquarters personnel are supplemented by the use of personnel in the national laboratories, particularly at ORNL, but there is a real need for additional headcount in the headquarters group if they are to carry out proper supervision of projects within their program and provide the necessary follow-through so that the results of their research eventually becomes of value of the industry.

There are some areas of research that are quite clearly the responsibility of the federal government and at least a few of these fall within the assigned responsibility of DOE's EES Division. To cite some examples: the program that they initiated about 18 months ago to evaluate the possible impact of electromagnetic pulses from high altitude nuclear explosions on the nation's transmission and distribution systems is extremely important. While some limited studies could be carried out under the auspices of the power industry itself or by EPRI, it is critically important that such an issue be evaluated by a group with full access to the substantial Government data and resources necessary for complete assessment. Moreover, the possible impact of EMP on the nation's electrical systems is of prime concern to our national defense and, as such, is clearly a federal responsibility.

Another example in which the same kind of considerations are important is the biological effects of both electrostatic and electromagnetic fields emanating from power lines. While it is possible that these concerns are only perceived rather than real at present levels of exposure of the public, it is important that EPRI's work in this area be augmented by complementary studies by DOE.

There are several other areas of work planned or underway by Electric Energy Systems Division that could benefit by modest increases in the budget available to them. These include advancement in normal and emergency operating concepts in large power systems, basic research into failure mechanisms of electric insulation, and both the hardware and software aspects of active load management concepts. Specific projects that are underway that may require additional funds to permit them to be brought to logical conclusions include the superconductivity technology program that has been going on for many years at MIT and the Hawaiian deep water cable project. While this latter project is critical to the proposed transmission of geothermal power between different islands in the Hawaiian chain, it will probably have useful fallout for other applications of deep water cable.

In summary, it would be my recommendation that, through appropriate adjustments of the overall DOE budget, the EES Division budget should be restored at least to the former level of about $40 million (exclusive of energy storage) and that it include adequate funds for personnel resources sufficient to plan, carry out and oversee a research program across their areas of responsibility. I pledge EPRI's full cooperation to such an activity.

Mrs. LLOYD. We are very happy to have with us our friend, Mr. Collins. We certainly do welcome you today. Mr. Pat Collins is Under Secretary of Energy. We look forward to hearing from you.

I want to say for the benefit of all of our witnesses today that your prepared statements, your complete statement will be made a part of the record in its entirety. In the event that any of you today want to summarize your remarks, you may do so.

We are happy to have you with us, Mr. Collins. We are also happy to have with you Ms. Donna Fitzpatrick who is principal deputy assistant secretary for conservation and renewable Energy; Mr. Streb, who is deputy assistant secretary for conservation; and Dr. San Martin, who is deputy assistant secretary for solar and renewable energy. We are certainly delighted to have all of you with us today.

Mr. Collins, you may proceed.

STATEMENT OF HON. PAT COLLINS, UNDER SECRETARY, U.S. DEPARTMENT OF ENERGY

Mr. COLLINS. Thank you very much, Madam Chairman. I certainly agree with your remarks, and I would like to have our statement entered in the record in full, and then I will just summarize it.

Mrs. LLOYD. Without objection.

Mr. COLLINS. As you know, Madam Chairman, when I assumed the position of Under Secretary, the Secretary of Energy, Don Hodel, gave me a special charge to improve the Department of Energy's programs in conservation and renewable energy. In that light, we have worked extensively with the members of this committee and their staff, and deeply appreciate the input that we have gotten on those programs.

Mrs. LLOYD. We certainly have enjoyed working with you and your staff, too, Mr. Collins.

Mr. COLLINS. Thank you, Madam Chairman.

One of my first initiatives was to establish a thorough review of the ongoing and proposed programs and assure that adequate funding was available and that adequate coverage would be provided for a broad spectrum of technological options. The budget for the three programs under discussion today was developed in concert with our fourth national energy policy plan which was announced by the Secretary and the President in the White House in October 1983 and fully supports the goals and strategies set forth in that NEPP-IV.

The overall goal is to foster an adequate supply of energy at reasonable costs. This policy recognizes that adequate supply requires a great deal of flexibility in the energy system, with no undue reliance on any single source of supply. The goal of reasonable cost suggests economic efficiency within that energy system.

Our strategies for achieving this energy policy goal were to minimize Federal control and involvement in energy markets, while maintaining public health and safety, and environmental quality, and promotion of a balanced and mixed energy resource system.

The fiscal year 1985 budget implements the strategy by supporting the development of a mix of technologies that can contribute to energy supply and end-use energy efficiency. In allocating our resources, we are concentrating in applying Federal funds only where they are most effective and sponsoring research and development where the potential payoff is high but where private industry cannot be expected to pursue, because the return on investment would require an exceptionally long time to be realized, and because results are difficult to predict or highly risky.

The Department's electric energy and energy storage programs provide vital linkages between energy supply, energy conversion, and energy end use. The hydropower program provides a technology base needed to assist in reestablishing the U.S. small hydroelectric industry.

The highlights of our requests in the electric energy systems, the budget request for $18.2 million is divided into four principal areas: electric field effects research, $3.7 million; reliability research, $4.5 million; systems technology, $9.3 million; and program direction and equipment, $0.7 million.

Let me give a few examples of some of the types of projects that we would like to pursue.

As you are very well aware, the use of high voltage a.c. and d.c. is growing rapidly in our country. There is considerable concern that the electric fields generated by these transmission systems could present a potential health hazard to humans and animals. In fiscal year 1985, we plan to continue to identify health thresholds and hazard levels, if any, of electric field exposure, and determine methods for extrapolating data from tissues and cell studies from lab animals to humans.

With regard to reliability research, we plan to continue and expand our work in electromagnetic pulse research, in computer aided technologies, and in development of more effective operating strategies and corrective actions for electric systems during normal and emergency operating conditions.

In the area of systems technologies, we want to continue to develop concepts and methods to increase efficiency and effectiveness of the Nation's electric utility networks. For example, in fiscal year 1985, we plan to complete our testing of the world's first prototype superconducting transmission line and assess the capability of it.

Although no funds are requested in the fiscal year 1985 budget for the Hawaiian deep water cable project, I would like to point out that the project will continue. This research concerns submarine cables for transmission of electric power designed for depths of 7,000 feet and is over 170 miles long. No other funds are requested because the project had some initial delays in getting started and prior Congressional appropriations are sufficient to carry it through fiscal year 1985.

In the energy storage area, the budget request is $17.1 million, divided into three primary areas: battery storage, $14.8 million; thermal and mechanical energy storage, $1.3 million; and program direction and capital equipment, $0.95.

The Storage Program aims to provide the needed battery technology for electric vehicles, electric utility load leveling, and enhance the intermittent renewable energy resources by providing continous service. The battery storage request includes funds for research to improve materials and components of cells and batteries. It is also directed at obtaining understanding of electrochemical phenomena such as corrosion and define ways to alleviate this as a major energy consuming problem.

Experience, I think, has shown us that the materials limitation within the electrochemical area are the principal cause for failing to meet cost and performance goals in the past. Therefore, much of our research focuses on developing improved materials to achieve improved energy efficiency, high energy and power densities, lower capital cost, and increase life cycle.

The battery storage work includes continuing development of the aluminum air battery. The current prime contender as the energy source for electric vehicles and utility load leveling is the sodium sulfur battery. The present successful development of this system will be continued in fiscal year 1985 with emphasis on improving life and reliability. This battery appears capable of providing five times the energy storage capability per unit of weight of present commercial lead acid batteries.

Work will continue in 1985 on the zinc bromine battery for electric utility application. Our funding request is to improve the materials stability and durability for the system.

In the thermal and mechanical storage area, we plan to work on two activities: thermal energy storage and chemical/hydrogen energy storage. This work is directed toward achieving low-cost materials and techniques for use with industrial heat recovery, solar heating and cooling, and load leveling in the electric utilities.

Fiscal year 1985 chemical storage will include investigations of water/freon compounds for near room-temperature use and form stable phase-change materials such as salt-ceramic composites.

The hydrogen activities will focus on developing efficient, cost-competitive processes for producing hydrogen from water and providing the technology for safe and cost-effective storage, transmission, and distribution.

In the hydropower area, the budget request is for $.5 million. I point out that 11 of the 19 previously funded, cost-shared powerplant demonstrations are now on line. We intend to continue to monitor maintenance experience for a 2-year period. Most of our budget request is planned to go in this area and to disseminate the result to the private sector.

Lastly, the Department plans to monitor low-cost, cross-flow turbine field testing as well as the EPRI project on prefabricated hydropower systems.

In conclusion, we believe that the Department's budget for these three programs, electric energy systems, energy storage and hydropower are balanced and provide an objective approach toward achieving individual program goals while maintaining technological leadership in each of these very important areas.

Thank you, Madam Chairman.

[The prepared statement of Mr. Collins follows:]

Statement of
Pat Collins
Under Secretary
U.S. Department of Energy
Before the
Committee on Science and Technology
Subcommittee on Energy Research and Production
U.S. House of Representatives
March 7, 1984

Madam Chairman and Members of the Subcommittee, I appreciate this opportunity to appear before you today and provide information on the FY 1985 budget request concerning the Department's Electric Energy Systems, Energy Storage, ~~and~~ Hydropower programs. The budget for these programs was developed in concert with the Fourth National Energy Policy Plan (NEPP-IV), published in October 1983, and fully supports the goals and strategies set forth in that document. I will summarize those parts of the Plan which are relevant to the subject of today's hearing, discuss related highlights of the FY 1985 budget request, and address the areas of interest identified in your letter of invitation.

NATIONAL ENERGY POLICIES AND STRATEGIES

The overall goal of our national energy policy is to foster an adequate supply of energy at reasonable costs. The policy recognizes that "adequate supply" requires flexibility in the energy system, with no undue reliance on any single source of supply. The goal of "reasonable costs" suggests economic efficiency within the energy system, so that energy consumers, individual, commercial, and industrial users alike, are not penalized by economic rigidities introduced into the system by ill-advised governmental regulation. The strategies for achieving this energy policy goal are: (1) to minimize Federal control and involvement in energy markets while maintaining public health and safety and environmental quality; and (2) to promote a balanced and mixed energy resource system.

The FY 1985 budget request implements these strategies by supporting development of a mix of technologies that can contribute to both energy supply and improved end-use efficiency. We are concentrating Federal funds where they are most effective: sponsoring research and development (R&D), where the potential payoff is high but which private industry cannot be expected to pursue alone.

In support of these strategies, the Electric Energy Systems Program and the Energy Storage Program provide vital linkages between energy supply, energy conversion, and energy end use. The Hydropower Program provides a technology base needed to assist in reestablishing the U.S. small hydroelectric industry. I will describe each program's funding request and justification separately.

ELECTRIC ENERGY SYSTEMS

The FY 1985 budget request for the Electric Energy Systems program is $18.2 million. These funds will be used to support research aimed at increasing the efficiencies, reliabilities, and adaptability of our Nation's electric power transmission and distribution systems. The work entails important yet diverse activities that include: testing of the only prototype superconducting transmission line in the world (this was designed and developed earlier in the program); conducting health effects research to evaluate the ultimate effects on humans and animals of exposure to electric fields from high voltage power lines; and achieving an understanding of the effects on the electric network of electromagnetic pulse (EMP) generated from high-altitude nuclear detonations.

More specifically, the Electric Energy Systems (EES) program supports research aimed at: (1) determining the biological health effects and risks to humans, plants, and animals exposed to high-voltage electric fields in use and planned for future use by the Nation's electric utilities; (2) providing technology options that will enhance reliability of the Nation's future electric networks under all normal and emergency situations; and (3) improving the efficiency of electric delivery systems through the development of new materials, advanced controls, and new design concepts. Thus, the EES program supports research that is of nationwide importance, affecting the ultimate cost of power to the consumer as well as security of the electric energy systems. To make an impact on these issues requires a sustained effort and longer range view than any individual utility, group of utilities, or research arm of the utilities can support alone.

The Electric Energy Systems program ($18.2 million) is divided into three subprograms: Electric Field Effects Research ($3.7 million), Reliability Research ($4.5 million), and Systems Technology ($9.3 million). In addition, the FY 1985 budget requests $0.3 million for capital equipment, and $0.4 million for program direction. The basis for these funding requests follows.

Electric Field Effects Research ($3.7 million) will be continued in FY 1985 in order to identify health thresholds and hazard levels of electric field exposure and to determine methods for extrapolating data from tissue and cell studies and from laboratory animal experiments to humans. Effort will be increased in FY 1985 on determining the mechanisms by which electric fields interact with biological materials and on devising a methodology for human health effects analysis. Research has shown that there are some biological effects from exposure to high voltage alternating current (AC) fields but the biological mechanisms triggering those effects are still unknown and must be determined. Preliminary data on the biological mechanisms interacting to stimulate effects has encouraged regulators (State and Federal) to put off restrictive regulations until more conclusive research is completed in this program.

The use of high voltage direct current (DC) as a transmission option is rapidly growing in the U.S. A major unknown is the impact of DC electric field effects on living organisms. Research in this area will be expanded in FY 1985. Recent articles in the popular press tie certain forms of cancer to electric and magnetic field exposure. Public concern is growing and research is required to understand this phenomenon and to provide the scientific basis for legal and legislative decisions that may be required in both the AC and DC electric power transmission areas.

Reliability Research ($4.5 million) will be continued and expanded in FY 1985 in order to: (1) assess the impact of a nuclear electromagnetic pulse (EMP) on the Nation's electric network by expanding the modeling of the electric systems and their vulnerability to EMP, verifying such a model, and identifying where new materials or system design and control concepts may be required to minimize the impact on the electric network; (2) develop computer-aided technologies which will enhance the reliability of electric power systems during normal and abnormal operation, by expanding the use of microprocessors into the control and protective processes on electric networks and applying the latest mathematical theory to the complex network control problem; and (3) continue to develop more effective operating strategies and corrective actions for electric systems under stress.

Research in the area of electromagnetic pulse (EMP) is directed to assess the potential damage from a high altitude nuclear detonation and to determine plausible options to protect the network from a catastrophic shutdown. New strategies may be required which may be quite different from those which deal with only local disasters. Also, new protective concepts and operating strategies may be required. As the severity of such an event is quantified relative to the damage to the electric network, the program will be adjusted to address the new knowledge gained. During the past year, initial work was completed on how EMP effects couple into the electric network. This is a fundamental step required before the interaction of the EMP transient with the network and the level of potential damage to electric power systems can be evaluated.

As the U.S. electric network expands, it also becomes more complex and system reliability becomes an increasingly important and difficult problem. Abnormal system conditions are hard to detect as early as may be required to take proper remedial action and, when a major outage does occur, the question becomes how best to restore the network. New mathematical theory is being developed, new computer-controlled control concepts explored, and new protective schemes envisioned which, in real time, will assist operators in keeping the network intact and operational during both natural and man-made emergencies.

Systems Technology efforts will be continued in FY 1985 ($9.3 million) with the aim of increasing the efficiency and effectiveness of the Nation's electric utility networks. This work is closely coordinated with EPRI and much of this work is conducted by the equipment supplier community. Activity will continue on the superconducting transmission cable project. This project, has shown for the first time that a long (100 meter) superconducting system can be successfully operated. The task will now be to finish the critical electrical impulse tests and, if successful, transfer the technology. Spin-off benefits from this low temperature work have provided a new insulation material and a design concept for ambient temperature cables. An important part of this latter activity that will be addressed in FY 1985 is the transfer of this technology to the cable manufacturing industry in the U.S.

Present forecasts indicate that high voltage direct current (HVDC) transmission may be an improved alternative to alternating current (AC) lines for the transfer of bulk power and research will be increased in FY 1985 on this method of power transmission. A synergism between the DC lines and the existing AC network may greatly improve the economic benefits. It is possible that improved system control would decrease the need for other more costly system components and still maintain service with acceptable reliability during all system conditions. Present HVDC technology limits its application to single line designs; circuit interrupters and multiterminal control technologies will be explored further in FY 1985 to address this limitation.

The recommended budget also provides for continuation of our efforts to develop concepts to automate systems and process data to substantially impact the operation and control of future transmission and distribution circuits. Microprocessor and computer technology is making possible a new era of real-time analytical ability which can sort out and process tremendous amounts of system data. Properly processed and communicated, this then can supply human operators with information upon which to base better decisions for operating these increasingly complex systems. Much of this is done at universities where advanced mathematical and control systems theory is developed as part of the research. During the past year we completed system design on the Athens/TVA distribution automation and control experiment. This experimental installation will integrate a large system (TVA) with automatic controls on the distribution system of the Athens Utility Board which will give opportunity to more nearly optimize total system operations and reduce costs of electricity to the consumer. A series of detailed experiments will be carried out during FY 1985.

Activity will also increase in exploratory development of a new generation of materials for future components and systems. These materials will include electrical insulating materials, magnetic conducting materials, and power semiconductor materials. This work will concentrate on understanding the basic molecular structure of the materials and will include an attempt to model the material and then see if it is practical to tailor materials more nearly to their use.

This effort will focus on improved efficiency (reduced losses), higher reliability, and lower cost, all of which will reduce system total life costs and provide the technology base required to win the economic battle with foreign competition. About 10% of the electric energy is dissipated into electrical losses, thus even small improvements in net system efficiency can outweigh the cost of the new materials if properly integrated into equipment designs.

Although no funds are requested in the FY 1985 budget for the Hawaii Deep Water Cable (HDWC) Project, I would like to point out that the Project will continue. This research concerns submarine cables designed for depths of over 7000 feet and lengths up to 170 miles; present state-of-the-art cables are good for 1800 feet and about 50 miles. To date conceptual design options have been developed for the electrical cable and associated deployment systems for deep water applications. No funds are requested in FY 1985 because the HDWC project had some initial delays in getting started and prior Congressional appropriations are sufficient to carry the project through FY 1985 and into FY 1986 at the planned project schedule.

Finally, $0.3 million is requested for capital equipment. These funds will be used to provide small, but essential, laboratory equipment for research in electric field effects and in systems technology at various DOE national laboratories. The $0.4 million requested for program direction provides for six full-time positions to develop the overall strategies and to plan and conduct the EES program described above.

ENERGY STORAGE

For FY 1985 the Department requests $17.1 million for the Energy Storage program. This program serves as the nucleus for virtually all research activities related to energy storage within the Department of Energy. The aim of the program is to develop energy storage technologies that will assist the private sector to provide efficient, reliable, economic, safe, and environmentally acceptable energy storage systems. The program goals are to provide the technology to: (1) underpin industry development of electrochemical power sources for transportation; (2) increase the operating economy of electric utility systems through load leveling; (3) permit intermittent renewable resources to provide continuous service; and (4) increase productivity by improving the efficiency of industrial electrochemical processes. The energy storage activities are coordinated closely with EPRI and the systems development work is conducted mainly by industrial teams.

The Energy Storage Program is divided into two subprograms: Battery Storage and Thermal and Mechanical Energy Storage. The Battery Storage activity focuses on battery and fuel cell research and development, on ways to reduce or eliminate corrosion, and on improvements in electrochemical processes to reduce energy consumption. The Thermal and Mechanical Energy Storage activity focuses on thermal energy storage to provide more effective building heating and cooling and chemical energy storage (hydrogen) to develop a technology base for the more economical use of hydrogen.

The FY 1985 budget request for Energy Storage of $17.1 million includes $14.8 million for Battery Storage, $1.3 million for Thermal and Mechanical Energy Storage, $0.5 million for capital equipment, and $0.45 million for program direction.

The Battery Storage ($14.8 million) subprogram supports activities in technology base research and exploratory technology development and testing. The technology base research activities encompass fundamental research with the overall objective of providing the basis for improvements in existing battery systems and the identification and development of new battery and fuel cell systems. Objectives of the exploratory technology development and testing activity include development and evaluation of high-performance, long-life, economical, and producible batteries for future mobile and stationary energy storage applications. Both activities are designed to fill the gap between fundamental research on promising electrochemical systems and the product engineering capabilities of industry. Projects are sponsored for developing multicell designs, establishing their base-line performance by evaluating batteries using uniform testing, and transferring the technology to the end-use sector organizations of the DOE Conservation program, to the DOE Solar program, and to private industry.

Two aims of the technology base research are to improve materials and components of cells and batteries and to understand selected electrochemical phenomena, including corrosion. Experience has shown that materials limitations within electrochemical systems are the principal cause for failing to meet necessary cost/effective system-performance goals. Improved materials and components will lead to improved energy efficiency, lower capital cost, and increased cycle life, energy, and power density of electrochemical devices.

The continuing aluminum-air battery project is part of the technology base activity and is aimed at providing an energy source for general-purpose vehicle applications. The battery appears capable of providing driving range between recharges equal to that of present internal combustion engine (ICE) vehicles. The successful development of an aluminum-air battery would provide the impetus for commercialization of the general-purpose electric vehicle that could be fully competitive with ICE-powered vehicles. In FY 1984 a potentially low cost catalyst was developed. Research will be continued during FY 1985 on the air cathode needed to further improve life and cost. The construction of the first fully integrated multi-cell battery stack is planned for FY 1985.

A deeper understanding of the complex mechanisms that govern electrochemical processes will establish a scientific base to support research aimed at improving battery lifetime, cost, and performance. Results will facilitate improvements in battery systems and other electrochemical devices. FY 1985 activities will include research to understand electrochemical phenomena and corrosion.

In FY 1985, the exploratory technology development and testing activities will concentrate on sodium-sulfur and zinc-bromine batteries, as well as testing and post-test analysis of other types of batteries. The sodium-sulfur battery has the potential for the highest performance of any of the battery systems currently in the exploratory development phase. This battery appears capable of providing five times the energy storage capability per unit of weight of present commercial lead-acid batteries. In addition, this battery appears capable of higher efficiency of operation. In FY 1984 a 36 kilowatt hour engineering model was built and tested. The FY 1985 activities will emphasize continued development of cells with improved life and reliability.

The zinc-bromine battery is a flowing electrolyte system with potential for meeting many of the performance and economic requirements of stationary energy storage and electric vehicle applications. The zinc-bromine battery has over twice the energy storage capability of present commercial lead-acid batteries and potentially lower cost. A 20 kilowatthour battery is being constructed for test and evaluation in a photovoltaic system. Core technology studies in FY 1985 will emphasize improvement of materials stability and durability, improvement in specific power, and understanding of basic electrode mechanisms and thermal management. Test facilities at Sandia National Laboratory and at the National Battery Testing Laboratory (Argonne) fulfill the need for independent evaluation to provide the basis for judging progress and permit an unbiased assessment of the state-of-the-art of battery technology. The goal of the testing activities is to evaluate the performance, life, and failure modes of advanced prototype batteries under careful laboratory control. Life and performance problems are identified and the results are used to direct research efforts aimed at solving the problems. In FY 1984, post test analysis of a sodium/sulfur battery revealed that corrosion of the cell container was a major problem which limits battery life. This has resulted in the initiation of a technology base research project on corrosion. Batteries currently under test include sodium/sulfur, zinc/chlorine, zinc/bromine, advanced lead-acid, nickel/zinc. In FY 1985, activities will include testing of prototype load-leveling sodium/sulfur and zinc/bromine modules.

The Thermal and Mechanical Storage ($1.3 million) subprogram includes two types of activities: thermal energy storage and chemical/hydrogen energy storage. The goals of this work are to develop low-cost, sensible heat, latent heat, and thermal chemical heat storage components for solar thermal power, industrial heat recovery, solar heating and cooling, and electric utility load management.

In the Thermal Storage activity in FY 1984 direct contact heat exchanger work using molten salt/air in a packed tower at 350°C will be completed. This work verifies the potential for economic savings by use of a high-temperature direct-contact heat exchanger. FY 1985 activities will focus on storage media and systems-related problems (i.e., heat transfer, insulation, and containment). The potential applications vary over a wide range of temperature, from 0° to 10°C for cool storage, to as high a 1100°C for solar thermal storage. Thermal storage projects related to storage media will include investigation of form-stable, phase-change materials such as salt-ceramic composites for higher temperature applications and water/freon compounds for near room-temperature applications. An advanced cool storage concept will also be investigated incorporating a solid-state radiative heat pump to charge the system.

In the Chemical (hydrogen) activity in FY 1984 the feasibility of a high temperature fuel cell (single cell) operating in the electrolysis mode to generate hydrogen was demonstrated. This hydrogen generation cell will have higher electrical efficiency than lower temperature systems. Chemical/hydrogen energy storage activities in FY 1985 will focus on developing efficient, cost-competitive processes for producing hydrogen from water and providing the technology for safe and cost-effective storage, transmission, and distribution of hydrogen. Activities involved in high-temperature (1000°C) electrolysis will involve modifications of solid-oxide electrolysis cells for generation of hydrogen. In addition, work will be conducted in the Integrated Test Bed, such as experiments on stand-alone electrolyzer systems.

For FY 1985, $0.5 million is requested for capital equipment. Equipment is required for cell/module and post-test analysis at the National Battery Test Laboratory. Equipment required for advanced battery testing includes battery cyclers, temperature measuring electronics, battery voltage scanners, furnaces, and furnace controllers. Equipment is needed for the Van der Graaff accelerator at Los Alamos National Laboratory, the light source at Brookhaven National laboratory, and for investigation of electrochemical reactions in batteries and fuel cells at Lawrence Berkeley Laboratory. Finally, $0.5 million is requested for program direction, which will support six full-time-equivalent positions.

HYDROPOWER

The FY 1985 budget request for Hydropower is $0.5 million. This includes $0.4 million for Technology Support and $0.1 million for Program Direction. Small scale hydropower is comparatively mature technology that uses the Nation's streams and smaller waterways as an energy source to produce electrical power. The DOE program focuses on monitoring a number of projects funded through prior years and transferring the results of those projects to the non-Federal community.

The Technology Support activity will enable the program to continue technical monitoring of ongoing projects and to disseminate results of these and other efforts to the private sector. Monitoring will principally concentrate on demonstrations of hydroelectric facilities and several engineering research and development projects. Eleven of 19 previously funded cost-shared power plant demonstrations are now on-line. DOE plans to observe the operation of maintenance experience of completed projects for a two year period. Two more plants are scheduled to begin operation during each fiscal year in 1984 and 1985. The Department will also monitor low-cost cross-flow turbine field testing, and the Electric Power Research Institute (EPRI) prefabricated hydropower system project. Results from Department-sponsored activities will be communicated to the private sector and public utilities through a technology transfer program as a means of facilitating further development. For example, EPRI and DOE are jointly funding a major hydropower technology transfer effort to evaluate the approximately 50 projects funded by the Department over the past five years and transfer the lessons learned to industry and state and local governments. The requested amount for Program Direction will support personnel resources for about one equivalent staff year.

CONCLUSION

The budget submitted for FY 1985 represents a balanced and objective approach to achieving program goals and maintaining technological leadership in the areas of Electric Energy Systems, Energy Storage, and Hydropower. Therefore, we ask that this budget request be given every consideration for funding at the levels requested.

Thank you for the opportunity to testify today.

Mrs. LLOYD. Thank you very much, Mr. Collins.

We are very happy that our ranking minority member, Mr. Walker, is with us today. We welcome you. If you would like to present your statement.

Mr. WALKER. Thank you, Madam Chairman. I understand that you have given permission for my statement to be put in the record and——

Mrs. LLOYD. And there was no objection. [Laughter.]

Mr. WALKER. I am glad to hear that. That is probably surprising, so I will let it rest with that good work already done.

Mrs. LLOYD. Mr. Collins, the budgetary history of these programs in recent years, as you well know, has been one of a rather persistent effort to either eliminate or strictly limit the government's work on many of the critical programs that you and I both discussed. I think it has been through the actions of the Congress that we have been able to stabilize these efforts and also permit a rather modest increase in the funding.

It is pretty apparent in this request for 1985 that most of the programs are again being decreased as a partial offset. Would you elaborate for us on how the 1985 funding and manpower levels compare to those of 1984?

Mr. COLLINS. Madam Chairman, I think in the manpower areas, that the levels that we have are relatively consistent with the 1984 budget. There is a 3-person total difference.

Mrs. LLOYD. You discussed the programs, and I would like to go into a little bit more detail, but what projects are being terminated or decelerated as a result of the budgetary actions, and is it going to be a serious problem for some of the programs?

Mr. COLLINS. Madam Chairman, it certainly requires some leadership of those who are working in the national labs and some managerial assistance along that line. There are no programs that were cut out of the previous budget. As a matter of fact, although relative to the amount appropriated by Congress, it is not exactly the same, it is, as you well know, an increase in what we have proposed in many of these areas in the past. In fact, our overall conservation and renewable budget from the President this year is about 200 percent of what it was last year, increased. In fact, in the overall conservation and renewable area of the Department, there is about a 340-percent commitment increase over last year.

We have proposed more than we had in the past because of conversations with people that share your views on this that we should be closer to what the Congress wanted and possibly we could have a better position at the bargaining table to be able to talk about the basic and applied programs that are included.

Mrs. LLOYD. Well, so many of our programs are at the breakthrough level, which you well know.

Mr. COLLINS. Absolutely, and I think that in that sense there weren't any that were eliminated. Some of the priorities were refocused.

Mrs. LLOYD. You know, of course, we do cover a broad range of programs in our Energy Storage Programs, our electrochemical storage technology that will lead to advanced battery systems. The second area focuses on thermal and mechanical storage technology, thermal and chemical hydrogen. It seems that both areas are proposed to be significantly cut in these programs, so my question to you is what are the real significant accomplishments of last year in the storage programs? Which ones do you think will be leading candidates for further developments?

Mr. COLLINS. Madam Chairman, as I highlighted just a bit in the testimony, certainly the sodium sulfur battery looks to be a potential winner in this area with at least 500 percent more capacity that other batteries. In fact, some people suggest it may even be twice that high.

I think that the work in hydrogen, that we are proceeding along that level in the physical and the chemical appropriation area. There is, as I mentioned also or alluded to in my testimony, some phase change work that we are doing that offers some very interesting possibilities even in residences, and certainly not necessarily in business or industrial only. In some of the areas in the physical and chemical technologies, we have reached a milestone where we think that generally the basic and applied research or proof of concept has been completed and that we should not have a great deal more activity in those areas.

Also, I think that this year that we are completing our research in the hydropower areas, as well, and would be going into a technology transfer mode on that.

Mrs. LLOYD. What other countries are involved in this area of research and development? Are they as involved as we are in such programs?

Mr. COLLINS. Quite a few are. I think that in the energy storage, for example, West Germany, England, Japan, and Sweden are aggressively pursuing that. For example, some numbers, West German in the $29 million area, England is $12 million, Japan is $13 million I think. That is in the ballpark. Sweden is about $5 million.

However, I would say we are absolutely unique in the aluminum battery area. I think that on most of our battery work that we are ahead if not maybe dead even in one category with most of the foreign competitors.

Mrs. LLOYD. Is there any area where you feel we are behind?

Mr. COLLINS. I think in that particular area the worst is dead even on one technology.

Mrs. LLOYD. Mr. Walker?

Mr. WALKER. Thank you, Madam Chairman.

Let me pursue the battery question here a little bit. How much interest are you finding from commercial firms for spinoff of that development if we are at a point where we have achieved some significant breakthroughs? Are you getting any commercial entities that are interested in picking up on that?

Mr. COLLINS. Mr. Walker, I think I would like to have our Deputy Assistant Secretary, Al Streb, go into that in depth because it is very important at this stage.

Mr. STREB. We involve the industry, of course, in our work from the very beginning. I think you know well that the sodium sulfur battery, which is one of the most promising candidates, has a very strong interest in participation of Ford Aerospace. The zinc bromine battery as well. There is a commercial interest in pursuing that.

I would like to further pass this along to Mr. Brogan who is the program Manager, here for further elaboration.

Mrs. LLOYD. Would you identify yourself, sir?

Mr. BROGAN. John Brogan.

Mrs. LLOYD. Please proceed.

Mr. BROGAN. Thank you, Madam Chairman.

Mr. Streb stated that from the beginning when it comes to the system development, we have heavily involved industry, as opposed to the national lab. The lab works in the fundamental areas supporting the contractors, in fact, who are the system developers.

In several of these developments, there is cost sharing. There has been from the beginning. For example, in the case of zinc bromine, Exxon is cost-sharing that 50-50 with the Department of Energy. There is a 25 percent cost-share with the aluminum battery work, 25 percent from Altech and Alcan, an aluminum company of Canada. We are anticipating significant cost sharing from Ford Motor Co. now that we have overcome a number of technical barriers in that sodium sulfur system.

In general, though, there isn't widespread support by battery companies or firms not directly related to battery companies, such as an Exxon, in putting up significant amounts of venture capital to take some of these technologies and move them faster into the marketplace. The technology just isn't quite there yet. It is closest to being real and viable in two of the three systems I mentioned, the zinc bromine and the sodium sulfur work.

However, the firms still don't see the market, a readily available market, without many more years of further development.

Mr. WALKER. Well, a couple of questions. First of all, one of the things that has always been a problem on adaption of battery technology to vehicular use has been two-fold, amount of storage capacity which you seem to be talking about overcoming to some extent with some of the new battery technology, and weight. Are we also solving the weight problem with the battery technology that you are talking about?

Mr. BROGAN. Yes, we are. It is tied into the term used in that field; energy density. Energy density is related to how far you can go before recharge.

Mr. WALKER. Having said that, what also strikes me is, being somewhat of an automobile nut, I keep fairly close to some of the developments in the industry, and it seems to me that nearly every major manufacturer, not only in this country but worldwide, has dropped their electric vehicle programs. Some of the people that were projecting toward going to some kind of an electric vehicle by the mid 1980's or by the late 1980's have dropped the concept of production. That is what leads to my question then of why are we not seeing the commercial entities respond on the vehicular side?

Second, what are the problems of some of the battery companies? Even if somebody doesn't want to build an electric car, or an electric truck, it seems to me that some of the battery companies might well want to move toward giving us a 10-year battery rather than the present maybe 3-year kind of capacity we have in cars and various other storage places now.

Mr. BROGAN. The battery market today is very lucrative, or the aftermarket. It is running around $2 billion a year. That is very lucrative considering the fact that virtually not a red cent is being put into improving those batteries because the manufacturers feel they don't need significant improvements. So, they are making money.

Mr. **Walker**. So what you are telling is there is not very much enthusiasm out there for a 10-year battery that would last the life of the car when the fact is that what they are doing right now is selling batteries to people who buy the car on the second round or even to original owners that drive their car for more than 3 years.

Mr. **Brogan**. That is right. There is not a buck to be made in it unless some significant breakthrough occurs in the electric chemistry and materials dealing with lead acid batteries.

Mr. **Collins**. Mr. Walker, if I may just expand on that briefly. As Mr. Brogan mentioned, we have a $10 billion market overall, $2 billion in just lead acid alone, and I think the Secretary and I are committed to keeping our eye on conservation. We are concerned that during this last 2-year period where petroleum prices have leveled off to some degree that a lot of people are taking their eye off that goal. There is an assumption that we are never going to have a problem again, that the problems in the Middle East are not as serious as we perceive them, and I think that this is actually the time that we have the ability to be able to concentrate on some of these types of activities. Also, of course, our battery work, as you well know, not only applies to the electric vehicle but to other activities as well.

Mr. **Walker**. Sure, but I am also thinking of the prioritizing that we have to do in this committee. Now, if in fact we are developing a long-term battery that no one wants because it would totally realine the entire battery industry, that has to be a concern for us. If we are in fact developing technology for a high-capacity, low-weight battery that no one in Detroit or Stuttgart or Tokyo or anyplace else wants to build, I think that we have got to understand that in terms of the prioritizing we do in the budget, too. Essentially, I am coming around to that question, after we have developed these batteries, who is going to buy them?

Mr. **Streb**. Mr. Walker, I would like to comment first of all on the priorities that we have in the program. I think you perhaps have noticed a great increase in the emphasis on sodium sulfur. That is because we have a great deal of hope for sodium sulfur as being the battery of the future perhaps for vehicular applications.

The problem, of course, with electric vehicles has been the weight of the batteries. Sodium sulfur does offer the promise of at least a factor of 5 and perhaps even a factor something higher than that in terms of the storage capacity per unit weight which should make electric vehicles a viable commodity.

The question is, with that great——

Mr. **Walker**. Let me interrupt you there. What kind of range are we talking about?

Mr. **Streb**. The electric vehicle that we currently have with the lead acid battery, we are able to squeeze 65 or 70 miles out of it. It is a very heavy vehicle, fairly expensive vehicle, and I think sodium sulfur, if it is a factor of 5 better than that, should arrive at a point which is similar to what you are able to achieve with a conventional battery.

Mr. WALKER. So you are talking about a 250- or 300-mile range with an overnight recharge?

Mr. STREB. I am not sure that you get quite that far, but I think you do get to the point of being competitive with the conventional car.

Your other question is one with that great promise, why aren't the battery manufacturers, the vehicle manufacturers jumping on board and pursuing that. I think the answer is that there is still substantial technological problems to be solved. We are looking at many fundamental problems that we see answers to and we think our program is addressing them and is solving them, but it is far enough down stream, perhaps 7 years, that the businessman really can't jump in yet or doesn't have sufficient incentive to jump in. We would hope in the very near future that we begin to see more involvement and we are going to encourage more involvement in the private sector so that gradually we can phase out.

Mr. WALKER. Well, I am over my time now, but just one more follow through. It still doesn't answer the question, why somebody like GM who actually had programed an electric vehicle into their production schedule at one point with a release date I think it was 1986 or 1987 has now evidently, from everything that I read, backed out of that concept. At a time when new technology seems to be coming along and what you are saying to us is that there is more hope for this, yet we see companies that had previously committed backing off. That is what gives me some concern and some pause.

Mr. COLLINS. Mr. Walker, we are under the impression that they are still working on this and that they had problems of batteries and that is one of the reasons that it wasn't as successful. I think the other part is there are other automotive improvements that have not been introduced into the market. We are quite convinced that is because of, and quite frankly some automobiles were getting a little larger in size and we have seen the reports about that in the media as of late, that people are taking the last 2-year situation for granted, the situation in the Middle East for granted.

The Secretary and I don't. We think that both the situation in the Middle East is, as Senator Jackson often told us, is one incident away from some serious problems, and that we must proceed along this line or else we will end up losing a great deal of progress, number one, and not be where we want to if it rears its head again like it did in 1973 and 1974.

Mr. WALKER. Well, you are absolutely right and I am disturbed too that I see a consumer trend out there which has to be worrisome to any of us that have looked at the future at all, where consumers have all of a sudden decided that the big car is back and automobile companies have had to keep production lines up for cars that they were planning on getting rid of because they were not fuel efficient vehicles. You can't blame the automobile companies either. They needed some profitability somewhere along the line too, but you do have to question consumers who have decided that 15 to 18 miles to the gallon is good enough again and we will just hope that nothing happens because they will be back into us then and if something does happen, they will be back into your Deparment. They will be back into us in Congress telling us that you have got to do something to protect us on prices and everything else because I just bought this brand new car that only gets 18 miles to the gallon, and you can't expect me to go out and buy a new fuel efficient car if the whole thing comes apart.

So, we really do have some serious problems in that regard. Even so, at a time of budgetary problems that you are as aware of as we are, I also have to feel that when we look at our priorities and what we have got to do in terms of the flexibility of the funding that we allocate, we have to look at what is likely to end up being utilized most efficiently and most readily. I must admit that some of the trends here bother me.

Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much, Mr. Walker.

I would like to go back to the original question I gave you on the cutbacks in our three specific programs. I would like a little bit more information on the projects within these programs that have been terminated, if you have it.

Mr. COLLINS. Madam Chairman, I would be glad to provide a list for the record, but some of the ones that——

Mrs. LLOYD. Well, if you will provide it for the record, we would certainly appreciate having it. That would be fine.

Mr. COLLINS. Fine.

[The information follows:]

ENERGY STORAGE PROJECTS SCHEDULED FOR TERMINATION IN FISCAL YEAR 1985

Project	Fiscal year—	
	1984 estimate	1985 request
Battery storage:		
Molten salt cell research	$1,950	0
New battery systems	200	0
Iron-air battery	400	0
Thermal and mechanical storage:		
Direct-contact heat exchange	500	0
High-temperature thermal storage	600	0
Hydrogen storage research	600	0
Hydrogen embrittlement research	500	0
Seasonal thermal (underground) storage	1,200	0
Superconducting magnetic storage	350	0

Mrs. LLOYD. I would like to go back to the Hawaiian deep water cable project. I think it is supposed to be phased down by $4.8 million in the 1985 budget; $10.8 million has been appropriated from 1982 to date for the project basically because Congress earmarked the funds for that, but the rate of appropriations has exceeded the flow of funds in support of the project activities which are really about a year behind, as you well know.

Therefore, you are not requesting the funding. There is serious question as to whether or not this project is really appropriate long-range R&D of the same significance as our other long-range R&D programs. The other programs seem to have equal merit but are being eliminated or delayed because we don't have the money.

What is the full program plan this year for this project?

Mr. Collins. Madam Chairman, this program looks like instead of the original plan of 3 years it would certainly take 4 years.

Mrs. Lloyd. What is the current status of it then?

Mr. Collins. They are mainly in the planning phase of this. I actually went out and viewed this, and talked to the contractors involved. They think that basically they have spent about a year more—they are going to spend more than a year planning than they originally had in mind. It would be $11 million to complete it. Of course, we are talking about a depth of 7000 feet and a length of about 175 miles as opposed to the previous depth that had been reached which was about 1800 feet and only an 80-mile length in the Norway to Denmark cable.

I have gone over the plans and problems with them. It appears that they have—and I understand them and I think that they are approaching it in a business-like manner, but I do think that obviously we are in an area that we haven't even come close to approaching before in this industry.

Mrs. Lloyd. I didn't mean that this was not appropriate R&D, but I was thinking that there are other programs that I think are of equal merit.

What does this program—what is its merit compared to those that are getting lesser priority in terms of the high risk and the high payoff?

Mr. Collins. Some people say it is site specific. I would say that the technology could be able to be utilized around the world. There have already been companies on the mainland expressing a desire to market that technology.

Mrs. Lloyd. Is it a technology of great transfer?

Mr. Collins. There are some significant areas where it could be utilized, but as far as how many copies, I don't know how great a number that would be. If we can reach these depths and we can retain the viability of it for this distance, I think it may open up many more markets.

Mrs. Lloyd. Let's go on to our small-scale hydroelectric program. We have funded this program, as you well know, to develop a technology base to really reestablish if we could a vigorous hydropower industry. The program I think has received about $70 million beginning in our 1977 budget and the DOE has ordered an orderly reduction of this program.

What is the potential for developing of the low head applications? What is the market really out there?

Mr. Collins. It has had a dramatic increase since the Congress expressed interest in it in 1977, when we were actually pretty much out of the low head hydro market. I remember I was working with the Congressman here on the Hill who had that type of a district where it could be utilized, and we couldn't really get any decent technology.

Mrs. Lloyd. And we heard from the Congressman from that part of the country at that particular time.

Mr. Collins. Yes. I think that what is exciting is we are having about 1,000 applicants per year now in the either permanent process, an exception process, or the licensing. We have gone as high as 2,000 in that.

I think that a lot of these are farmers and ranchers, of course, and irrigation districts, and relatively small operators, but I think that that is extremely effective. We have developed some very good small-tech technology along this line, and we are completing three research projects this year alone. At that point, I think we will be from an R&D standpoint where these people generally small business people, will be able to take advantage of this.

I understand we have about 6800 MW on line and 200 MW on construction, and we think there is a potential of over 25,000 MW.

Mrs. LLOYD. 25,000 MW. That is certainly significant.

Are there any institutional obstacles to licensing of the small plants either on private or Federal land?

Mr. COLLINS. They have to go through the Federal Energy Regulatory Commission, of course, and quite frankly, to get a relatively small project, we are talking 6 months; to get a larger project, up to about 24 months, so far. Of course, that is without a great deal of opposition. If you have substantial opposition, that could be expanded even further.

Mrs. LLOYD. What is the history on the opposition? Is it a major factor?

Mr. COLLINS. About 80 percent have not had any, Madam Chairman.

Mrs. LLOYD. Well, we consider licensing for other facilities in this committee. This is very insignificant period of time.

We do thank you for being with us today and for your excellent staff being with you.

Are there any other comments that any of you or your colleagues would like to make?

Mr. COLLINS. No, thank you, Madam Chairman.

Mrs. LLOYD. Again, we are delighted that you could be with us today. Thank you very much. We certainly appreciate working with you.

Next we are going to hear from our witnesses from our laboratories as well as other outside witnesses. Our first panel will include Dr. Fritz Kalhammer, who is vice president of energy management and utilization from the Electric Power Research Institute. We have Mr. Lowell Endahl, who is manager of energy research and technological development from the National Rural Electric Cooperative Association.

You gentlemen all have very long titles. We are very happy to have all of you distinguished gentlemen here today.

We have Mr. Donald Helfrecht, who is president of Madison Gas & Electric Co. and also president of Wisconsin Electric Utility Research Foundation; and Mr. William Feero, representing the Institute of Electrical and Electronic Engineers, Inc.

As we stated earlier, we do have your complete testimony, and you may proceed as you wish. Your entire statement will be made a part of the record of our hearings today.

Dr. Kalhammer, please proceed.

STATEMENT OF DR. FRITZ KALHAMMER, VICE PRESIDENT FOR ENERGY MANAGEMENT AND UTILIZATION, ELECTRIC POWER RESEARCH INSTITUTE

Dr. KALHAMMER. Madam Chairman and members of the subcommittee, I am Fritz Kalhammer, vice president of energy management and utilization at the Electric Power Research Institute. On behalf of EPRI, I would like to thank you for this opportunity to appear before you and present some of our thoughts on the need for continuing Government sponsored R&D in electric energy systems, energy storage, and small-scale hydropower.

I will attempt to point out areas where we believe DOE funding is insufficient to accomplish the objectives of what we believe to be important closely coordinated Government/private sector programs, and I will identify some of the adjustments that we believe are needed within the existing budget.

By way of background, since my division's responsibilities do not precisely coincide with those of the DOE Division of Electric Energy Systems, I will confine my remarks in this area to my own responsibilities within EPRI. I understand that John Dougherty who is vice president of EPRI's electric systems division has submitted written testimony which covers the area of his division's expertise.

Mrs. LLOYD. Yes, we have his statement and it will be made a part of the record also.

Dr. KALHAMMER. Again, by way of background, I have been personally involved with the Government's energy storage activities since the formation of EPRI in 1973. In fact, during 1974 and 1975, I was cochairman of a joint ERDA/EPRI committee that was planning the battery energy storage test, or BEST, facility. My staff and I are genuinely proud of the exemplary relationship that we have established and maintained over all of these years with ERDA and then later with the DOE technical staff. These relationships have covered also hydropower in more recent years. Working in close coordination with DOE, I believe we have made excellent progress and we have moved several technologies from the point of laboratory research to the brink of commercial use.

There are a number of examples which I can refer to as successful cases of close cooperative DOE/EPRI efforts. I would like to quote here the work on air injection in aquifers which is basic to the feasibility of compressed air storage as a joint project. We have a joint project to disseminate the results of the DOE hydropower efforts that were alluded to earlier in testimony here today. We have developed and deployed two prototype hydrogen generators that have been successfully operating on two electric utility systems, providing hydrogen for generator cooling. Again, this technology is a result of joint DOE/EPRI programs.

We have an advanced 500 KWh zinc chloride battery module that is now installed in the BEST facility and has completed about 20 cycles. Finally, I would like to refer to an improved 500 kWh lead acid battery that is capable of very long life, 2000 cycles, and that is a candidate for the customer side of the meter energy storage. All are examples of successful cooperation.

In our view, these examples are only the beginning as we harvest the result of the collaborative research that we have put in place during the last 10 years. I believe that if we are persistent in these efforts, these and other products will be fully developed, and then eventually adopted by the private sector to yield benefits, such as oil displacement, lower costs of electricity to the customer, and so forth.

Specifically, by the late 1980's and early 1990's, we believe that there will be a pressing need for energy storage that can extend the use of the lowest cost sources of electricity, coal, and nuclear, while displacing higher cost oil and gas. Similarly, as has already been stated, it is important that we advance the techology of small hydro.

We think that we really only have relatively few years left to lay the development groundwork for the necessary energy storage alternatives and for lower cost hydro options. We believe we must be aggressive in our pursuit of these efforts, and we at EPRI have attempted to establish a program that, when taken together with the DOE program, is stable over sufficiently long periods to provide a clear message to the private sector.

Consistent with this perspective of an overall national program, we at EPRI have made many adjustments in our program during the last few years to compensate for the shifts in the DOE program. As it has shifted from nearer term to longer term, we have made a shift from longer term to nearer term emphasis.

Examples are that we have assumed sole responsibility for the compressed air storage test facility at Pittsfield; we have assumed sole responsibility for developing the high head pump turbine technology; we are now assuming a key role in the dissemination of the results of the DOE small hydropower program; and we have agreed to play the major role in procuring the developmental batteries to be tested and evaluated in the BEST facility.

I believe that shows that we at EPRI are willing to accept our share of the responsibility for R&D activities in energy storage and electric energy systems, but clearly, we have a limited budget, and the coordinated national effort that we have in the areas that we have built up over the last 10 years certainly relies importantly on continued participation by the Department of Energy.

With a view to this overall coordinated program and its nationally significant thrusts, there are several areas within the Government's proposed fiscal year 1985 budget request that appear to be insufficiently funded, as we said before, and we would like to encourage consideration of a number of adjustments. I would like to refer to some of these now.

The first area that I would like to address is the electric energy systems area and within it, particularly, systems technology. There, efforts should include support for the evaluation of load leveling batteries. We believe that the restoration of about $1.3 million would allow DOE to again participate as a sponsor of the BEST facility which we believe is a highly successful example of Government/private sector cooperation and risk sharing. This participation by DOE would accelerate the design and the development of prototype battery systems that then could be evaluated at the BEST facility. This is a very important role that DOE has played in close cooperation with EPRI as essentially an equal funding partner, and we believe it is most appropriate that this role continue into fiscal 1985.

In the area of battery energy storage R&D, there ought to be continued DOE funding essentially at the 1984 fiscal year levels. The advanced batteries, sodium sulfur, zinc chloride, zinc bromine, redox, et cetera, are now reaching the stage where small developmental battery systems can be fabricated and tested in the BEST facility which is close to a utility environment. We have agreed to be a major sponsor of such tests, but we can do it only if DOE is able to provide the supporting R&D that is vitally necessary to correct the expected technical deficiencies of these early preprototype batteries and to achieve cost effective technical solutions to these problems.

The present fiscal year 1985 budget is not sufficient to provide all of the R&D needed. For example, to point out a specific deficiency in the planned DOE budget, there is a lack of support for the zinc bromine battery R&D despite the fact that DOE and EPRI have structured a joint program wherein DOE will support the R&D, and EPRI will procure the developmental battery for evaluation at the BEST facility.

About $2 million from DOE in this area could be levering $2 million from EPRI and another $2 million from the successful developer. Correcting this and other areas in the battery R&D where funding is insufficient would require a budget for battery storage R&D of about $20 million.

Turning to DOE's past R&D in thermal and mechanical energy storage, this R&D has already yielded several important outputs that have been adopted by the private sector. I have previously mentioned the aquifer compressed air energy storage and the onsite hydrogen generator results. I believe that these successes should encourage the government to pursue additional exploratory R&D in the thermal and mechanical energy storage area.

Advanced concepts that decrease the use of oil and gas in compressed air energy storage systems, hydrogen production concepts based on advanced electrolysis, or perhaps photoelectrochemical concepts are examples of the activities that might be considered in the DOE program. An fiscal year 1985 budget for these activities of about $4 million, in our view, would be appropriate. EPRI's budget in those areas is about $3 million, but it is strictly directed toward near-term applications and does not contain funds for longer-term, more exploratory R&D.

Finally, turning to the area of small hydropower, the technology transfer efforts that were established by DOE's small hydropower program have enabled EPRI to become involved in this national effort. We will have a number of joint projects with DOE that range from disseminating the results of the small hydropower demonstration projects to pursuing R&D on lower-cost equipment alternatives.

This has been a very effective DOE activity with enormous leverage on the private sector. EPRI is funding hydroelectric generation efforts at about $2 million per year, and we believe that DOE's funding should be at a corresponding level to continue the completion of the small hydropower demonstration activity and the dissemination of the results, the areas that had been mentioned by the Undersecretary.

In closing, I want to assure you that EPRI is committed to do its part in supporting near-term technologies and expediting the commercial application of these technologies. However, we must look to the Department of Energy to sponsor the exploratory and supporting R&D. Without this R&D, the technical risks in adopting these new technologies will remain too high for the private sector, and the exploration of yet more advanced, socially beneficial concepts will not occur.

This concludes my statement. Thank you for this opportunity to provide you with my thoughts.

[The prepared statement of Dr. Kalhammer follows:]

STATEMENT OF FRITZ R. KALHAMMER
VICE PRESIDENT, ENERGY MANAGEMENT AND UTILIZATION DIVISION
ELECTRIC POWER RESEARCH INSTITUTE
to the
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
March 7, 1984

Madame Chairman and Members of the Subcommittee:

I am Fritz R. Kalhammer, Vice President, Energy Management and Utilization Division for the Electric Power Research Institute. On behalf of EPRI, I would like to thank you for this opportunity to appear before you and present our thoughts on the need for continuing Government-sponsored R&D in electric energy systems, energy storage and small-scale hydro power.

Since my division's responsibilities do not precisely coincide with those of DOE's Division of Electric Energy Systems, I will confine my remarks to the areas of my expertise. I understand that John J. Dougherty, Vice President of EPRI's Electrical Systems Division, has submitted a written statement pertaining to the areas of his division's expertise.

I have been involved with the Government's energy storage activities since the formation of EPRI in 1973. In fact, in 1974-75 I cochaired the joint ERDA-EPRI committee that planned the Battery Energy Storage Test (BEST) Facility. My staff and I are proud of the exemplary relationships that have been established and maintained with the ERDA and later the DOE technical staffs for over a decade. These relationships cover hydro power as well as energy storage activities. Working in close coordination, we have made excellent progress and moved several technologies from the research stage to the brink of commercial use.

The following are a few of the recent results of the cooperative DOE-EPRI efforts,

- o The feasibility of using aquifer storage for compressed air energy storage plants was proven by the test of such an aquifer at Pittsfield, Illinois.
- o A joint project to disseminate the results of DOE's small hydropower program was implemented and preliminary results are now available.

- o Two prototype hydrogen generators have been successfully operating on utility systems for over a year, providing make-up hydrogen for cooling electric generators.
- o An advanced 500kWh zinc-chloride battery module was installed in the Best Facility and has completed 20 successful cycles.
- o An improved 500kWh lead acid battery capable of 2000 charge-discharge cycles was installed at the BEST Facility; it is being evaluated for customer-side energy storage.

I am confident that these examples represent only the beginning, as we harvest the results of the collaborative research that we have put in place. And if we are persistent in our efforts, these and other products will be fully developed and adopted by the private sector, yielding the expected social benefits. Specifically, by the late 80's and early 90's, there will be a pressing need for energy storage technologies that can extend the use of our low cost sources of electricity while displacing the higher cost oil and gas alternatives. Similarly we must do everything possible to expand the use of hydropower.

We have a relatively few years to lay the groundwork for the necessary energy storage alternatives and lower cost hydro options. Thus, we must remain aggressive in our pursuit of these efforts. We at EPRI have attempted to establish a program that, when linked to DOE's, is stable over a sufficiently long period of years to provide a clear message to the private sector. Consistent with this overall program perspective, we at EPRI have made many adjustments to our programs during the past few years to compensate for DOE's shift from near-term to longer-term emphasis. For instance:

- o We assumed sole responsibility for the compressed air energy storage test facility at Pittsfield, Illinois.
- o We assumed sole responsibility for developing the high head pump-turbine.
- o We are assuming a key role in disseminating the results of the DOE small hydropower demonstration program.
- o We have agreed to play the major role in procuring developmental batteries for evaluation at the BEST Facility.

While EPRI is willing to accept its share of the responsibility for these activities, our budget is not without limit, and the coordinated national effort relies importantly on DOE's continued participation. EPRI supports the efforts of the Congress and the Administration to reduce budget deficits. However, we would like to recommend a higher priority within the overall DOE budget request for several important areas which appear insufficiently funded. Specifically, we would encourage the following adjustments:

Electric Energy Systems

- Systems Technology efforts should include support for the evaluation of load levelling batteries. The restoration of $1.3 million would allow DOE to again participate as a sponsor of the BEST Facility--a highly successful example of Government-private sector cooperation and risk sharing--and it would accelerate the design and development of prototype batteries systems that would be evaluated at the BEST Facility. This is an important role that DOE has played through FY83 in partnership with EPRI. EPRI's budget for this activity will be about $1.5 million in FY85.

Energy Storage

- Battery Storage R&D should be continued at the FY84 level. Advanced batteries (sodium-sulfur, zinc-halogen, redox, etc.) are reaching the stage where small developmental battery systems need to be fabricated and tested in a utility environment. EPRI has agreed to be a major sponsor for such tests, but it can do so only if DOE is able to provide the supporting R&D vitally necessary to correct technical deficiencies and achieve cost effective technical solutions. The present FY85 budget is not sufficient to provide all of the R&D needed. For example, a major deficiency in the planned DOE budget is the lack of support for the zinc-bromine battery R&D despite the fact that DOE and EPRI have structured a joint program wherein DOE will support the R&D and EPRI will procure the developmental battery for evaluation at the BEST Facility. In effect DOE's $2 million could be levering $2 million from EPRI and another $2 million from the successful developer. Correcting this and the other areas where funding is insufficient would require a budget for battery storage R&D of about $20 million.

- DOE's past R&D in Thermal and Mechanical Energy Storage has already yielded several important outputs that have been adopted by the private sector. I have previously described the aquifer compressed air energy storage and the on-site hydrogen generator results. I believe that these successes should encourage the Government to pursue exploratory R&D in these areas. Advanced concepts that decrease the use of oil or gas in compressed air energy storage systems, and, hydrogen production concepts based upon advanced electrolysis or photoelectrochemical concepts are examples of activities that might be considered. A FY85 budget for these activities of about $4 million would be appropriate. EPRI's budget in those areas is about $3 million, but it is directed toward near-term applications and does not contain funds for longer-term exploratory R&D.

Small Hydropower

- The technology transfer efforts that were evaluated by DOE's Small Hydropower Program have enabled EPRI to become effectively involved. We will have a number of joint projects that range from disseminating the results of the small hydropower demonstration projects to pursuing R&D on lower cost equipment alternatives. This has been a very effective DOE activity with enormous leverage on the private sector. EPRI is funding hydroelectric generation efforts at about $2 million/year; DOE's funding should be at a corresponding level to continue the completion of the small hydro power demonstration activity and the dissemination of the results.

In closing, I want to assure you that EPRI is committed to do its part in supporting nearer-term technologies and expediting the commercial application of those technologies. However we must look to DOE to sponsor exploratory and supporting R&D. Without this R&D, the technical risks in adopting new technologies will remain too high for the private sector, and the exploration of yet more advanced, socially beneficial technical concepts will not occur.

This concludes my statement. Thank you for this opportunity to provide you with my thoughts.

Mrs. LLOYD. Thank you very much, Dr. Kalhammer. I appreciate your statement. We will have some questions for you later, and you reinforce my position that the work of this committee is to fund the programs for long-term R&D for applications that are further down the line. I certainly think your goals are in the right direction with the EPRI work and put the financial resources on the shorter term areas of research and development.

Mr. Endahl, please proceed with your testimony.

STATEMENT OF LOWELL J. ENDAHL, MANAGER, ENERGY RESEARCH AND DEVELOPMENT, NATIONAL RURAL ELECTRIC COOPERATIVE ASSOCIATION

Mr. ENDAHL. Madam Chairman, my name is Lowell Endahl, Manager of energy R&D for the National Rural Electric Cooperative Association. We appreciate the opportunity to present the NRECA membership views on these important topics that are being considered here today, electric energy systems, energy storage, and small-scale hydro programs.

NRECA, as you know, is the national service organization for some 1,000 rural electric cooperatives that provide electric service to approximately 25 million people in the rural and sparsely settled areas, agricultural areas, of about 46 States. These systems have approximately 44 percent of the distribution line. About 3 percent of the Nation's generating capacity and distribute about 11 percent of the Nation's electric power.

The research under consideration today is especially important and of a great deal of interest to the rural electric cooperatives. Research in these areas, we believe, can have significant economic value through their potential for improved efficiencies, and several of the programs under consideration also have national security implications. We are concerned because these aspects of research often have low visibility. They are often undervalued and, consequently, underfunded.

At the recent NRECA annual meeting in San Francisco, which was attended by about 9,000 people, the NRECA membership adopted a series of resolutions on energy use. Some of those resolutions are attached to my statement.

One resolution, in particular, "Research for Growth and National Security" called for a well-funded, long-range commitment for electric energy systems research and development within the Department of Energy, and urged a minimun funding of $20 million for this work in fiscal year 1985. The resolution points out that the EES is involved with several programs of critical national importance and, among them, is a study of the effects of electromagnetic pulse, as has already been mentioned. We support the increased level of funding proposed by the administration for the EMP research within the Reliability R&D budget.

The resolution also cites examples of other EES projects which require strong support including technologies for improved efficiency and reliability of power generation, transmission and energy storage, and the electric field effects of high voltage transmission lines. The funding proposed for electric field effects appears to be appropriate, but we would stress that a strong Federal presence in this work is essential for the objectivity and public acceptance of these research results.

Rural electric systems also support greater efforts in superconducting technology; control and analysis; and advanced electric energy battery storage systems. It is in these areas of system technology that we think that the fiscal year 1985 budget appears to be its weakest. It is this kind of research that holds promise for substantially improved operating generating and efficiency and better conversion of our Nation's resources to usable energy that should be continued as a responsibility of the Federal Government.

We are concerned about our understanding of the termination of the support for the battery energy storage test facility. The thrust of advanced batteries for load leveling is just beginning to pay off. With the interest that has been generated among manufacturers and utilities and with support of EPRI, we believe the Government could easily leverage its investment and help to bring into being a new technology that would have great benefit to the public. We have at least one rural electric cooperative that is keenly interested in installing a load leveling battery system in conjunction with its load management scheme, but the research and the engineering is not complete and a product is not yet available to meet that utility's needs.

We believe that it is a mistake to discontinue this work at this time. Not only does it have potential value for utilities, but it can help to stimulate battery development for electric vehicles. We would urge that support for the BEST facility be reinstated at a level of about $1.3 million.

I was interested in the earlier discussion of the importance of the battery technology. I would like to cite an example of how the Federal Government has been responsible for stimulating new development. I am pleased to report to this committee that the NRECA research fund has funded a program in cooperation with South Dakota State University to develop an electric farm chore tractor. The idea for that tractor was a result of the DOE program which studied the potential of electric vehicles in agriculture. That study showed that farmers typically used tractors for chores around the farm less than 2 hours a day. This use, then, offers us an excellent opportunity to use battery technology.

From the responses we have seen from farmers, we believe that there is a market for such a technology. We don't have the problems with speed, range, or weight with an electric tractor. We intend to use state of the art lead acid batteries, but the potential for the tractor could certainly be enhanced by advanced battery development.

Rural electric systems, which are among the largest potential users of small-scale hydro also support continued research efforts in this area. We note that the proposed fiscal year 1985 budget for small hydro is only $500,000 for demonstration, monitoring, technology transfer, and research and development. We believe that about four times that amount, or about $2 million, might be a desirable amount to use for this work.

Mrs. LLOYD. I think you see a great potential for the small hydrofacility.

Mr. **Endahl**. Indeed, rural electric systems are very much interested in this.

We would also like to see a testing laboratory established where hydro turbines can be tested for performance characteristics and where experimental work can be done.

Finally, I would like to reemphasize one point that was made at hearings last year, and that is the trend toward shifting the responsibility for major research over to the private sector. I was glad to hear the chairman's response to that this afternoon.

The view of industry being able to carry forward and complete the research that the Government abandons simply is not realistic. We do need the Federal support for these kinds of programs. Electric utilities are constantly being called upon to spend huge sums of money to improve the environment, to increase reliability and, at the same time, try to keep the cost of electric power low, so they do need Federal support for these research efforts.

The programs that we have discussed here today are relatively small, but they are important. Many of them have suffered drastic cuts in the past several years. The electric energy systems group, I understand, has only four professional staff members today compared with 25 or 30 of 4 years ago. We urge you to give this dedicated staff the support it needs in terms of funding and in terms of additional staff to help carry out and meaningful and productive program.

In summary, we would like to see funding increased for the electric energy systems to at least $20 million with battery energy storage test facility reinstated at about $1.3 million and additional funding for the superconducting generator for automation processing concepts and for EES staffing. We also urge increased funding to about $2 million for the small-scale hydro program.

We appreciate the opportunity to present these views.

[The prepared statement of Mr. Endahl follows:]

STATEMENT OF
NATIONAL RURAL ELECTRIC COOPERATIVE ASSOCIATION
to the
ENERGY RESEARCH AND PRODUCTION SUBCOMMITTEE
HEARING ON FY 85 AUTHORIZATIONS FOR
DOE ELECTRIC ENERGY SYSTEMS AND ENERGY STORAGE R&D

Washington, D.C.
March 7, 1984

Madame Chairman and members of the Committee: My name is Lowell J. Endahl, manager of Energy Research and Development for the National Rural Electric Cooperative Association (NRECA). We appreciate the opportunity to present the NRECA membership views with respect to the U.S. Department of Energy funding and activities relating to Electric Energy Systems, Energy Storage and Small Scale Hydro programs.

NRECA is the national service organization which represents nearly 1000 non-profit, consumer-owner rural electric systems which deliver electric power to approximately 25 million people in the rural and sparsely populated agricultural areas of 46 states. These relatively small cooperatively-owned electric utilities are located in about 2,600 of the nation's 3,100 counties, and they own and operate about 44% of the miles of distribution line in the United States to serve less than 10% of the nation's population. They own only about 3% of the nation's generating capacity, and they distribute about 11% of the nation's electricity.

The research under consideration today relating to electric energy systems, energy storage and small scale-hydro is of particular interest and importance to rural electric systems. Research in these areas can have a significant economic value through their potential for improved efficiencies, and several of the programs under consideration also have national security implications. We are concerned that, because these aspects of research have low visibility, they are often undervalued--and consequently underfunded.

At the recent NRECA annual meeting (January 23-25) in San Francisco, attended by nearly 9,000 people (mostly directors and managers of rural electric systems), the NRECA membership adopted a series of resolutions on energy issues of concern (resolutions attached).

One resolution in particular, "Research for Growth and National Security" called for "a well-funded, long range commitment for Electric Energy Systems (EES) research and development, within the Department of Energy, and urged minimum funding of $20-million for this work in the FY 1985 budget. The resolution points out that "These areas (electric energy systems research and fuel cell development) have national security implications as well as the potential for providing opportunities for growth and energy self sufficiency." The resolution points out that EES is involved with several programs of critical national importance. Among them is the study of the effects of Electro Magnetic Pulse (EMP) which, in the event of strategic military weapon explosions in the atmosphere, could distrupt communications and immobilize the entire electric generation and delivery system in this nation. We support the increased level of funding proposed by the Administration for this Reliability R&D work.

The resolution also cited examples of other EES projects which require strong support including technologies for improving efficiencies and reliability of power generation, transmission and energy storage, and the electric field effects of high voltage transmission lines. The funding proposed for electric field effects appears appropriate, although a very strong Federal presence in this work is essential for objectivity and public acceptance of research results.

Rural electric systems also support greater research efforts in superconducting technology application systems; control and analysis; and advanced electric energy (battery) storage. It is in these areas of Systems Technology that the proposed FY '85 budget appears to be weakest. We note that plans are to phase out the work on the 10 MVA superconducting generator research program. It is this kind of research that holds promise for substantially improved generating efficiency, and better conversion of our nation's resources to useable energy that should be continued as a responsiblity of the Federal government.

Another program, that we believe is prematurely scheduled for termination, is the support for the Battery Energy Storage Test (BEST) facility. The thrust for advanced batteries for load leveling is just beginning to pay off. With the interest that has been generated among manufacturers and utilities, and with support from the Electric Power Reserarch Institute, the government could easily leverage its investment and help to bring into being a new technology that would have great benefit for the public. At least one rural electric cooperative is keenly interested in purchasing a load leveling battery system to use in its load management scheme. But the research and engineering is not complete and there is not yet a product available to meet the utility's needs. We believe that it is a serious mistake to discontinue this promising research work at this time. Not only does it have potential value for utilities, but it can help provide the stimulous to battery development for electric vehicles. We urge that support for the BEST facility be reinstated at a level of about $1.3 million.

Considering the importance of battery technology, I would like to cite an example of how the Federal government has been responsible for stimulating new development. I am pleased to report to the committee that the NRECA research program is funding the development of an electric farm chore tractor in cooperation with South Dakota State University, The idea for the tractor was a direct result of a study initated by the Department of Energy on the potential for electric vehicles in agriculture. That study showed that farmers typically use tractors for chores around the farmstead less that two hours a day. This use offers an excellent opportunity to exploit the features of electric vehicles on the farm where the usual requirements for speed, range and weight are not problems. From the response we have received from farmers, we believe that there is a market for an electric chore tractor. We will use state-of-the-art lead acid batteries, but the potential for the tractor could be greatly enhanced by an advanced battery, and the BEST facility could play an important role in such a development.

Rural electric systems, which are among the largest potential users of small-scale hydro technology, also support continued research efforts in this area. The Department of Energy has nineteen small hydro demonstrations with facilites completed or underway, which must be monitored and progress reported. Results of these projects will enhance the development, licensing and management of numerous other small hydro projects throughout the nation. We note that the proposed FY 85 budget for small hydro is only $500,000 for demonstration monitoring, technology transfer and research and development. This is a reduction of $200,000 from the 1984 funding level. If we are to make good use of the small hydro potential of this nation, DOE should be investing four times that amount in this important program--at least match that of the Electric Power Research Institute. One of the important needs in the small hydro program is a national testing laboratory where hydro turbines can be tested for performance characteristics and where experimental work can be done. We respectfully request that $1 million be set aside for such a testing and experimental laboratory.

Finally I would like to reemphasize a point that was made at the hearings last year, and which was included in one of our membership resolutions. That resolution, which was reconfirmed at this year's annual meeting, expresses concern over the trend toward shifting the responsibility for major research (including costly, high-risk, short and long range projects) to the private sector. There appears to be a prevalent, but mistaken view that industry is in a position to carry forth and complete the research and development efforts that government abandons. EPRI, which rural electric systems support, has shown excellent cooperation in accepting as much of the burden as possible, but great demands have been put on the entire electric utility industry, and severe capital limitations prevent them from carrying out expanded research programs. Yet the needs are obvious.

The electric utilities are constantly called upon to spend huge sums of money to improve the environment, to increase reliability, and at the same time keep the cost of electricity as low as possible. They are trying. But they, and the public, need government support for research efforts that can help them to improve efficiencies and productivity in an environmentally acceptable way.

The programs that we have discussed today are relatively small, but they are important, and many of them have suffered drastic cuts in the past several years. In the Electric Energy Systems group, I understand that there are only four or five professional people remaining of a technical staff of 25 to 30 four years ago. We urge you to give this dedicated staff the support it needs in terms of funding and additional help to carry on a meaningful and productive program.

In summary, we would like to see funding increased for the Electric Energy Systems to at least $20 million, with the Battery Energy Storage Test (BEST) facility reinstated (about $1.3 million) and additional funding for the superconducting generator, for automation processing concepts, and for EES staffing.

We also urge increased funding to about $2 million for the small-scale hydro program.

We thank you for the opportunity to express these views.

RESOLUTIONS
Adopted or Reconfirmed
at the
NRECA Annual Meeting of Members
San Francisco, CA., January 25, 1984

Research for Growth and National Security

We support a well-funded, long-range commitment for Electric Energy Systems (EES) research and development and fuel cell development. These areas have national security implications as well as the potential for providing opportunities for growth and energy self-sufficiency.

We therefore urge the Administration and Congress to provide the following:

> Minimum funding of $20-million for FY 85 for Electric Energy Systems research within the Department of Energy. EES is involved with several programs of critical national importance. Among them is the study of the effects of electromagnetic pulse (EMP) which, in the event of a strategic military weapon explosion in the atmosphere, could result in a pulse from gamma rays that could create a surge 10 to 100 times faster that a lightning stroke. Such a pulse could disrupt communications and immobilize the entire electric industry. Other EES projects which require strong support include system technologies involving improving efficiencies and reliability of power generation, transmission and energy storage, and the electric field effects of high voltage transmission lines.
>
> A five year commitment, with a minimum of $40-million for FY 85, for fuel cell research and development. The potential offered by fuel cell technology for high efficient, dispersed electric power generation (so essential to national security) is enormous. Along with the potential economic advantages, the fuel cell has other very desirable characteristics (environmentally benign, short lead time for installation, modular design, and favorable load-following capabilities) which makes it truly a "tool for growth."

PRIORITIES FOR FEDERAL ENERGY RELATED RESEARCH

To meet America's future energy needs, we must develop every practicable energy source that shows promise of becoming feasible and environmentally acceptable through technological research and development.

Among projects that need adequate funding are: electric field effects; basic transmission and distribution systems research; superconducting technology application; systems control an analysis; and advanced electric energy (battery) storage.

Other technologies which show potential for commercialization and which deserve continued or increased funding and support by the federal government include the following:

* Fuel cell research and development;
* Gas Cooled and fast-breader reactors;
* Geothermal
* Peat, lignite and coal technologies (including gasification, liquefaction, fluidized bed combustion and MHD);
* Energy management and storage technologies (including compressed air, underground pumped hydro and battery storage);
* Solar energy systems (including residential heating and cooling, solar thermal, and photovoltaic generation of power); and
* More efficient small-and medium-scale power generation systems which can utilize coal and/or waste products and which can be used in a cogeneration mode.

We urge that in development and demonstration of each of these technologies special recognition and attention be given to their impact on, and compatibility with, electric utility systems. We further urge the federal government to coordinate these research efforts with EPRI.

EXTRA HIGH VOLTAGE TRANSMISSION LINE RESEARCH

The increased use of extra high voltage (EHV) overhead transmission lines for transmitting electric power by rural electric cooperatives is essential if we are to continue to provide electric power needs of rural America. Recent experiences in acquiring right of way and constructing such EHV lines have revealed serious misconceptions, mystique and fearfulness on the part of the general public as to the electric field effects on vegetation, animals and even people living in close proximity to such EHV lines.

Although such concerns are not supported by scientific evidence, we have an urgent need to provide positive, scientifically demonstrated evidence that there are no significantly adverse effects upon vegetation, animals and people living in close proximity to such EHV lines. NRECA urges the Congress and the appropriate federal agency to adequately fund electric fields research work involving both alternating and direct current overhead EHV lines and disseminate such information to the public.

ENERGY EFFICIENCY TECHNOLOGY

Conservation, by efficient production and use of energy, will play an important role in the present and future national energy strategy. Rural electric systems pledge their continued efforts to assist their member consumers in the wise and efficient use of electric power.

To maximize the potential for efficiency in electric energy production and use, however, considerably more effort on research, development and demonstration of new energy-efficient technology is urgently needed. This includes expanded research on load management techniques and equipment, and on the technology, economics and impact of integrating new sources of energy into existing utility networks.

In addition, work to further improve efficiencies in electric power distribution is needed. Distribution losses alone result in significant loss of peak load capacity of annual energy production. The annual value of such losses for the industry could be appreciably reduced with improvements in transformer loss characteristics, power and load factors, and other design and operating parameters.

We believe that further research can make such improvements economically feasible and we strongly urge the Administration and Congress to fully support an expanded long range program of transmission and distribution loss reduction research; and on such other technologies that might beneficially impact on the electric distribution system.

Mrs. LLOYD. Thank you for your very fine statement. We appreciate it very much.

Mr. Helfrecht, we look to you for your comments at this time.

STATEMENT OF DONALD J. HELFRECHT, PRESIDENT, MADISON GAS AND ELECTRIC CO., AND PRESIDENT, WISCONSIN ELECTRIC UTILITIES RESEARCH FOUNDATION

Mr. HELFRECHT. Thank you, Madam Chairman. I am Donald Helfrecht, president of Madison Gas and Electric Co. located in Madison, Wis. I also happen to be at the current time president of the Wisconsin Electric Utilities Research Foundation whose members are five of the investor-owned utilities that serve the State of Wisconsin and support research and development activities on an individual company basis, as members of the Electric Power Research Institute, and through our Foundation.

We certainly thank you for this opportunity to come and appear before you again. This is the fourth time a representative from our utilities' organization has had the privilege of appearing before you in support of the University of Wisconsin Madison's superconductive magnetic energy storage research project, SMES.

Mrs. LLOYD. We are happy to have you here today. We appreciate your fine contribution.

Mr. HELFRECHT. Thank you, Madam Chairman.

In the past, we have described for you in general terms the very significant advantages such an electric energy storage system would have to our utilities, our customers, our Nation, and in fact the world at large.

Superconductive magnetic energy storage, as conceived at Wisconsin, is a highly efficient energy storage system which takes the advantage of the characteristic of certain metals that in an extremely low temperature environment will conduct an electric current with no loss. The second primary advantage is the fact that SMES takes energy as alternating current, converts it to and stores it as direct current, and then returns it back to the power grid as alternating current by using the same system that placed it in storage in the first place. This is done on a daily cycle. A large magnet is charged during the nighttime hours using low-cost, off-peak generated power. The stored energy is then returned to the utility grid during the daytime peak period.

Only SMES stores electric energy without changing it to some other form of energy that is either thermal, chemical, mechanical, or kinetic. For this reason, SMES is 15 to 30 percent more efficient than all other types of storage.

SMES has several additional advantages over other forms of storage: It can replace the use of intermediate or cycling electric generating equipment. With its rapid power reveral capability of 33 milliseconds or less, it is possible to respond to system emergency condition. It acts as a spinning reserve component in our family of generating equipment. It provides system stability, and it also can be used to improve our system regulation. Another very important characteristic is that it can store electric energy which is produced by solar, wind, and photovoltaic devices whenever it is available for use as needed in the electric power network at a subsequent time.

Our electric utility industry has only a few means of electrical energy storage available to it. We need to develop better, more economical means of storage and SMES is the most efficient means known. It also is the newest, least known, and least funded of such technologies. The Electric Power Research Instititute completed an assessment of the SMES storage concept in July of 1983. This assessment found that a 1,000 MW capacity unit, with a storage capability of 5,500 MWh could be competitive with cycling coal. EPRI has indicate support for the continued research on improvement of the SMES design.

The Wisconsin electric utilities separately funded a study to determine the value of SMES to a typical electric system. In a word, I can report that the study was an unqualified success.

This study established that there is a U.S. market potential for SMES of about 260 GWh or 52 units of the 5500 MWh each, which comes down to roughly one per State.

A model SMES energy transfer system used for experimental thyristor circuit studies has been successfully operated at the University of Wisconsin Madison. This system consists of two three-phase 10 kW thyristor bridges, two four-Henry liquid helium cooled coils, and a single board microcomputer control system. This system has been used for preliminary experiments on sophisticated controls of energy transfer and circuit behavior.

The first experiment involved balancing currents between parallel thyristor bridge circuits during a typical diurnal energy cycle. Success of this technique will lead to an efficient and economical system to be used for large diurnal systems. Future experiments are planned to further refine the current sharing technique and expand into simultaneous real and reactive power control.

In layman's language, what this means is that the experiment has proven its capability to properly control the large numbers of parallel a.c. to d.c. conversion equipment necessary to produce the huge direct currents necessary in the SMES system. The success of this experiment is another significant milestone in the development of SMES.

With the position that this Nation has taken on the continued development of nuclear power, with Congress refusal to continue its funding of Clinch River breeder reactor, with the increasing emphasis on air and water purity, particularly with respect to acidic deposition, it is imperative that we as a nation, through the electric industry, explore every avenue to extend the useful lives and increase the efficiency of our existing nuclear, coal, oil, and gas generation.

Magnetic energy storage can do this. It is on the leading edge of technology. It will be able to improve the efficiency and usefulness of our existing plants, reduce their maintenance needs, permit increased use of our more efficient plants, and reduce the use of the less efficient plants.

The construction of 52 SMES units across our United States will create work for several thousands of people in the construction industry. This device uses large quantities of high purity aluminum and aluminum alloy. Therefore, additional work is assured in the aluminum industry.

The research and development needed to prove the SMES technology is small compared to other national storage program efforts. A 4-year, $15 million program has been proposed and this program will complete the following items: component research and development of the conductor material; investigation of the structural capabilities and the type of struts to be used to support it; the development of the helium container which provides the low temperature enclosure in which this magnet operates; and the design, excavation, and construction of the trench in which it is necessary to place the unit in the ground.

It is proposed that a small storage magnet coil of 10 kWh capacity be designed in the first 3 years of this 4-year program. Then it would be constructed and tested. In the fourth year, an investigation of that design and test would be analyzed and a decision would be made whether to proceed with a pilot plant project or not.

As a consequence of that development, the design of an optimized 100 MWh unit up to the potential of 10,000 MWh of storage capability would then be investigated. This effort would lead to a decision either to construct and test the 100 MWh demonstration storage unit or, if it does not justify such a decision, obviously the project would be put to bed at that point, with the minimal expenditure of $15 million.

A well documented proposal has been submitted several times to the Department of Energy by the University of Wisconsin at Madison for the $15 million 3 to 4 year program. Several man-years of effort from industry, the utilities, and the university went into forming that work schedule. Detailed descriptions were carried out to the level of each $10,000 expenditure with coinciding progress goals and time schedules.

Unfortunately, the Department of Energy has not supported our program recommendation. DOE declined to recognize the $2.9 million appropriated by Congress in the Senate's continuing resolution for fiscal year 1983. For that reason, on behalf of the Wisconsin utilities, I urge that the $15 million program be assigned directly to Wisconsin. If the Congressional assignment is unequivocally for Wisconsin, then our project would proceed. Otherwise, any funds you approved would likely be siphoned off by DOE for use in the national labs and not at Wisconsin.

The past 10-year record at Wisconsin proves that we have a strong university, industry, and utility team committed to a useful device. There is no reason for national lab involvement in this project.

Thank you, Madam Chairman.

[The prepared statement of Mr. Helfrecht follows:]

TESTIMONY
DONALD J. HELFRECHT
PRESIDENT, MADISON GAS AND ELECTRIC COMPANY
PRESIDENT, WISCONSIN ELECTRIC UTILITIES RESEARCH FOUNDATION

Thank you, Mr. Chairman. I am Donald J. Helfrecht, President of Madison Gas and Electric Company, located in Madison, Wisconsin. I am also President of the Wisconsin Electric Utilities Research Foundation whose members are five of the investor-owned utilities that serve the state of Wisconsin and who support research and development activities on an individual company basis, as members of the Electric Power Research Institute, and through our Foundation.

This is the fourth time a representative from our utilities and organization has had the privilege of appearing before you in support of the University of Wisconsin-Madison's Superconductive Magnetic Energy Storage (SMES) research project.

In the past, we have described for you in general terms the very significant advantages such an electric energy storage system would have to our utilities, our customers, our nation, and, in fact, the world.

Superconductive Magnetic Energy Storage, as conceived at Wisconsin, is a highly efficient energy storage system which takes advantage of the characteristic of certain metals that in an extremely low temperature environment (1.8 degrees K) will conduct an electric current with no loss. A second primary advantage is the fact that SMES takes energy as alternating current, converts it to, and stores it as, direct current, and returns it back to the power grid as alternating current by using the same system that placed it in storage in the first place. This is done on a daily cycle. A large magnet is charged during the nighttime hours using low-cost, off-peak generated power. The stored energy is then returned to the utility grid during the daytime peak period.

Only SMES stores electrical energy without changing it to some other form of energy, that is, either thermal, chemical, mechanical, or kinetic. For this reason, SMES is 15 to 30 percent more efficient than all other types of storage.

SMES has several additional advantages over other forms of storage:

1. It replaces intermediate generation;
2. Rapid power reversal (33 milliseconds is possible) to respond to system emergencies;
3. It acts as spinning reserve;
4. It provides system stability;
5. It improves system regulation;
6. It can store solar, wind, and photo voltaic produced electric energy whenever available, for use as needed in the interconnected electric power network.

Our electric utility industry has only a few means of electrical energy storage available to it. We need to develop better, more economical means of storage, and SMES is the most efficient means known. It also is the newest, least known, and least funded of such technologies.

The Electric Power Research Institute completed an assessment of the SMES storage concept in July of 1983. This assessment found that a 1000-MW capacity unit with a storage capability of 5,500 MHW could be competitive with cycling coal. EPRI has indicated support for continued research on improvement of the SMES design.

The Wisconsin electric utilities separately funded a study to determine the value of SMES to a typical electric system. The study was an unqualified success.

The study established that there is a U.S. market potential for SMES of about 260 GWH or 52 units of 5,500 MWH each, which is roughly one per state.

A model SMES energy transfer system used for experimental thyristor circuit studies has been successfully operated at the University of Wisconsin-Madison. The system consists of two three-phase, ten-kilowatt thyristor bridges, two four-Henry liquid helium cooled coils, and a single board microcomputer control system. This system has been used for preliminary experiments on sophisticated controls of energy transfer and circuit behavior. The first experiment involved balancing currents between parallel thyristor bridge circuits during a typical diurnal energy transfer cycle. Success of this technique will lead to an efficient and economical system to be used for large diurnal systems. Future experiments are planned to further refine the current-sharing technique and expand into simultaneous real and reactive power control. In layman's language, this experiment has proven the capability to properly control large numbers of parallel AC to DC conversion equipment necessary to produce the huge direct currents necessary in the SMES system. The success of this experiment is another significant milestone in the SMES development.

With the position this nation has taken on the continued development of nuclear power, with Congress's refusal to continue its funding of Clinch River Breeder Reactor, with the increasing emphasis on air and water purity, particularly with respect to acidic deposition, it is imperative that we as a nation, through the electric industry, explore every avenue to extend the useful lives and increase the efficiency of our existing nuclear, coal, oil, and gas generation.

Magnetic energy storage can do this. It is on the leading edge of technology. It will be able to improve the efficiency and usefulness of existing plants, reduce their maintenance needs, permit increased use of our most efficient plants, and reduce use of the less efficient plants.

The construction of 52 SMES units across our United States will create work for several thousand people in the construction industry. This device uses large quantities of high purity aluminum and aluminum alloy Therefore, additional work is assured in the aluminum industry.

The research and development needed to prove the SMES technology is small compared to other national storage program efforts. A four-year, 15 million dollar program has been proposed. This program will complete the following:

Component research and development of the conductor material, investigation of the structural capabilities and type of struts to be used the development of the helium container which provides the low temperature enclosure in which this magnet operates, and the design, excavation, and construction of the trench that is necessary.

It is proposed that a small storage magnet coil of 10-kilowatt-hour capacity be designed in the first three years of this four-year program; then it would be constructed and tested; and then in the fourth year an investigation of the design and test would be analyzed and a decision would be made whether to proceed with a pilot plant or not.

As a consequence of that development, the design of an optimized 100-megawatt-hour unit up to the potential of 10,000 megawatt-hours of storage capability would be investigated.

This effort, then, would lead to a decision either to construct and test the 100-megawatt-hour demonstration storage unit, or if it does not justify such a decision, obviously the project would be dropped at that point with the minimal investment of 15 million dollars that we have been discussing.

A well documented proposal has been submitted several times to D.O.E. by the University of Wisconsin-Madison for a 15 million dollar, three- to four-year program. Several man-years of effort from industry, the utilities, and the University went into forming the work schedule. Detailed descriptions were carried out to the level of each $10,000 expenditure with coinciding progress goals and time schedule.

Unfortunately the Department of Energy has not supported our program recommendations. D.O.E. declined to recognize the 2.9 million dollars appropriated by Congress in the Senate's continuing resolution for FY83. For that reason, on behalf of the Wisconsin utilities, I urge that the 15 million dollar program be assigned directly to Wisconsin. If the Congressional assignment is unequivocally for Wisconsin, then our project could proceed; otherwise, any funds you approve will likely be siphoned off by D.O.E. to a national laboratory and not to Wisconsin.

The past ten-year record at Wisconsin proves that we have a strong university-industry-utility team committed to producing a useful device. There is no reason for national lab involvement in this effort.

Thank you.

Mrs. Lloyd. Thank you, Mr. Helfrecht. That is certainly a very fascinating and intriguing proposal for consideration.

Mr. Feero, please proceed.

STATEMENT OF WILLIAM FEERO, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

Mr. Feero. Madam Chairperson and members of the subcommittee, thank you for the opportunity to present testimony. My name is William Feero, and I appear before you today on behalf of the Energy Committee and the Power Engineering Society of the Institute of Electrical and Electronics Engineers, the IEEE. The IEEE is the world's largest technical professional society with over 250,000 members worldwide, 200,000 of whom live and work in the United States.

The IEEE has an official institute position paper on "Electricity in the United States" which emphasizes the fundamental importance of energy availability to the welfare and economic health of society, which recommends an increased role for electricity in the Nation's energy economy, and calls for increased support of research and development to improve electric power efficiency and reliability, as well as advanced conversion technologies.

The IEEE has consistently supported the electric energy systems and the energy storage program in testimony before congressional committees having oversight over their budgets. We strongly support continuation of these programs. In fact, our gravest concerns lie in the need to continually enthuse the Congress and the administration to support the research of such programs as electric energy systems and energy storage. A lasting commitment to research in such a complex and critical area is essential. Continuity of research is espoused by the majority, but keeping both Government and industry involved in a consistent way has been difficult.

We do not live in a time of instantaneous inventions and instantaneous reward. Advancing technology requires hard, patient, and deliberate efforts for an extended period. Further, to advance technology in this modern world requires significant investment in people and capital resources. It cannot be attacked with a vengeance in 1 year or one administration and abandoned totally in the following.

Because of the importance of safety and reliability in the electricity supply, many technologies must be demonstrated at or near commercial scale in order to be acceptable to the electric industry. Sharing the risk of these projects and providing funds for construction of such facilities is a particularly difficult problem when budgets change dramatically from year to year.

We have reviewed the current electric energy systems and energy storage program plans and feel the proposals are worthwhile. These programs are planned by professionals. The programs are designed with a knowledge of the energy requirements of the United States and the mandated rules of funding research given by the Department of Energy. The guidelines for what is appropriate for active Government support is well articulated. The Government involvement is principally focused on areas that are crucial to the economic well being and security of the Nation and which are high-risk and long-term research areas.

These areas cannot or will not be attempted by nongovernment entities. Industry, principally through the Electric Power Research Institute, EPRI, is focused through its members to place emphasis on the solution of near-term problems. Manufacturers generally have not supported long-range, high-risk research, which yields no immediate payback or profit. Most require a return on their research investments within 5 years or less. Tax structures, foreign government-supported competition, and the growing cost-price squeeze all tend to limit manufacturer research support. Any such research that does exist is directed toward improvement of existing lines of equipment in which they have a heavy investment.

Internally supported research on system related problems is virtually nonexistent. Utilities' support of research is limited not only by their current financial problems, but also by regulation and local rate based pressures, and is generally limited to solutions of their own immediate problems and the support of the Electric Power Research Institute.

The idea of an appropriate government support of long-term, high-risk research is severely compromised by extreme shifts in funding levels. However, the current DOE administration seems to have a sound understanding of the needs and the funding required to meet these needs. We applaud this. We urge this commitment to research in the electrial energy area be consistently followed in the future.

The administration's 1985 budget submission presents a generally well laid out plan to press forward with the much needed applied research in the area of both electrical systems and energy storage. There are some obvious inconsistencies that appear to be more the result of excessive budget adjustments than poor design. A few examples are presented during the following discussion to emphasize that the budget may be overly restrictive.

The effort to understand how electrical systems will be affected by electromagnetic pulses is weakened by the elimination of studies of the breakdown mechanism of insulating materials. Such research may be included in the materials research portion of the budget. However, it appears to have been postponed.

Another inconsistency exists in the planning between the Electric Energy and Battery Storage Programs. The operating funds for the BEST facility, as you heard before, have disappeared. It is doubtful that the battery program can make any meaningful advancements without the use of a facility to test the functional characteristics of prototype advanced batteries and feed these findings back to researchers. If such a key part of the research in this area is a victim of budget pruning, funds should be found to prevent the loss of the availability of this facility to the research community.

Areas of research that are always begging support are those homely subjects that will not directly fit into any sponsor in terms of tangible payback. There is a total lack of visibility of new technology integration efforts. Most of the questions that must be answered in this area can find no individual research sponsor that will be able to profit by conducting the R&D.

For example, what is the real impact of harmonics? These are frequencies other than the 60 cycles that the system normally operates on. What are the problems created by harmonics from new source technologies on all power system apparatus? To find the answer will require significant efforts and may result in cost penalties to specific components and may limit the types of integration options. Since the true understanding of these effects can have negative connotations for specific constituencies, everyone seems to be avoiding the issue.

Is it not appropriate for the government, with a vested interest and a responsibility for an overall good, to get the answers to such questions even if the final results are hard to hold up as a desired accomplishment? Many such areas fit into the responsibility of a system group. Integration problems are far from being solved. A reasonable level of funding must be made available to pursue these subjects even though no single constituent can be found.

In the battery research program, there is a conspicuous lack of any new system exploration, yet money will be spent in the 1985 budget to define new systems. With the battery being the necessary component required to reduce the consumption of oil by the transportation and the utility infrastructure, how can we afford not to keep pressing for even more efficient and environmentally acceptable mobile and load leveling battery systems?

The zinc bromine battery is, by the discussion given in the budget, close to exceeding the capabilities of lead acid systems at a lower cost. Yet there is a significant reduction in the development testing necessary to provide the data which is essential to private enterprise to be able to evaluate the technical status and economic feasibility of these systems.

We cannot help but note that the programs are managed by a skeleton staff of dedicated individuals. We would suggest that to have a credible program, you need to have a credible management structure. That would suggest the Congress and the administration seriously consider strengthening the staffs to a level sufficient to manage the programs they have undertaken.

In summary, the administration and the Congress must not lose sight of the hard facts of research. From the inception of a research program to a commercial viability, a project may take 10 to 15 years to complete. We must be working today for systems to be available for commercial use in the next decade.

The electric energy systems and the energy storage programs are both concerned with crucial development that will require such lead times and continuity of funding through the whole R&D cycle to achieve these goals. While we sincerely appreciate the recent willingness of the DOE administration to rededicate the Government to working with the private sector to help solve these pressing problems, we believe additional funds should be allocated to these programs.

Events take place daily that clearly show the energy crisis of the 1970's can easily recur with its economic chaos. We must advance our energy system options to be better prepared to withstand pressures brought to bear by radical forces in the world. We are entering into a more vital period in our history. It is essential that we move back to the adequate funding of applied research and development programs in electrical technologies so that they will be ready when called upon to respond to the needs of the Nation.

Thank you.

[The prepared statement of Mr. Feero follows:]

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STATEMENT

BY

WILLIAM E. FEERO

On Behalf of the

ENERGY COMMITTEE

and the

POWER ENGINEERING SOCIETY

of the

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

HOUSE SCIENCE AND TECHNOLOGY COMMITTEE

March 7, 1984

STATEMENT
BY
WILLIAM E. FEERO
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BEFORE THE
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Madam Chairperson, members of the Subcommittee, my name is William E. Feero and I thank you for the opportunity to appear before you today on behalf of the Energy Committee and Power Engineering Society of the Institute of Electrical and Electronics Engineers (IEEE). The IEEE is the world's largest technical professional society with over 250,000 members worldwide, more than 200,000 of whom live and work in the United States.

The IEEE has an official Institute position paper on "Electricity in the United States" which has emphasized the fundamental importance of energy availability to the welfare and economic health of society, which recommends an increased role for electricity in the nation's energy economy and calls for increased support of research and development programs to improve electric power systems efficiency and reliability, as well as provide advanced energy conversion technologies.

The IEEE has consistently supported the Electric Energy Systems and the Energy Storage program in testimony before Congressional Committees having oversight over its budget. We strongly support continuation of these programs. In fact, our greatest concerns lie in the apparent need to continually enthuse the Congress and the Administration to support the research of such programs as Electric Energy Systems and Energy Storage Technology. A lasting commitment to research in such a complex and critical area is essential. Continuity of research is espoused by the majority but keeping both government and industry involved in a consistent way has been difficult. We do not live in a time of instantaneous inventions and instantaneous rewards. Advancing technology requires hard, patient and deliberate efforts for an extended period. Further, to advance technology in this modern world requires significant investment in people and capital resources. It cannot be attacked with a vengeance in one year or one administration and abandoned totally in the following. Because of the importance of safety and reliability in electricity supply, many technologies must be demonstrated at or near commercial scale in order to be acceptable to the electric industry. Sharing the risk on these projects and providing funds for construction of such facilities is a particularly difficult problem when budgets change dramatically from year to year.

We have reviewed the current program plan and feel that the proposals are worthwhile. These programs are planned by professionals. The programs are designed with a knowledge of the energy requirements of the United States and the mandated rules of funding research given by the Department of Energy. The guidelines for what is appropriate for active government support is well articulated. The government involvement is principally focused on areas that are crucial to the economic well being and security of the nation and which are high-risk and long term research areas. These areas cannot or will not be attempted by non-government entities. Industry, principally through the Electric Power Research Institute (EPRI) is focused through its members to place emphasis on the solution of near-term problems. Manufacturers generally have not supported long-range high risk research, which yields no immediate payback or profit. Most require a return on their research investments within five years or less. Tax structures, foreign government-supported competition, and the growing cost-price squeeze all tend to limit manufacturer research support. Any such research that does exist is directed toward improvement of existing lines of equipment in which they have a heavy investment. Internally supported research on new technologies, or on systems-related problems, is virtually non-existent. Utilities' support of research is limited not only by their current financial strait, which is increasingly severe in some regions of the country, but also by regulation and local rate based pressures, and is generally limited to solution of their own immediate problems and the support of EPRI.

The idea of an appropriate government support of long term, high risk research is severely compromised by extreme shifts in funding levels. However, the current DOE administrators seem to have a sound understanding of the needs and of the funding required to meet the needs. We applaud this. We urge that this commitment to research in the electrical energy area be consistently followed in the future.

The Administration's 1985 Budget Submission presents a generally well laid out plan to press forward with the much needed applied research in the area of both electrical systems and energy storage. There are some obvious inconsistencies that are more the result of excessive budget adjustments than poor design. A few examples are presented during the following discussion to emphasize that the budget may be overly restrictive.

The increased effort to understand how seriously the electrical system will be affected by EMP (high-magnitude, steep-front electrical pulses) is weakened by the elimination of studies of the breakdown mechanism in insulating materials. Such research may be included in the materials research budget. However, it appears to have been postponed.

Another inconsistency exists in the planning between the Electric Energy and Battery Storage Programs. The operating funds for the Battery Energy Storage

Test (BEST) Facility have disappeared. It is doubtful that the battery program can make any meaningful advancements without the use of a facility to test the functional characteristics of prototype advanced batteries and feed these findings back to the researchers. If such a key part of the research in this area is a victim of budget pruning, funds should be found to prevent the loss of availability of this facility to the research community.

Areas of research that are always begging support are those homely subjects that will not directly reward any sponsor in tangible payback. There is a total lack of visibility of new technology integration efforts. Most of the questions that must be answered in this area can find no individual research sponsor that will be able to profit by conducting R&D. For example, what is the real impact of harmonics (distorted voltage and current waveforms) created by new source technologies on all power apparatus? To find the answer will require significant efforts and may result in cost penalties to specific components, and may limit types of integration options. Since the true understanding of these effects can have negative connotations for specific constituencies, everyone seems to be avoiding the issue. Is it not appropriate for the government with a vested interest and a responsibility for an over all good to get the answers to such questions even if the final results are hard to hold up as a desired accomplishment? Many such areas fit into the responsibility of a system group. Integration problems are far from being solved. A reasonable level of funding must be made available to pursue such subjects even though no single constituent can be found.

In the battery research program there is a conspicuous lack of any new system exploration, yet money was spent in the 1984 budget to define new systems. With the battery being "the" necessary component required to reduce the consumption of oil by the transportation infrastructure, how can we afford not to keep pressing for even more efficient and environmentally acceptable mobile and load leveling battery systems? The zinc/bromine battery is, by the discussion in the budget, close to exceeding the capability of lead-acid system at a lower cost. Yet there is a significant reduction in the development testing necessary to provide the data which is essential if private enterprise is to be able to evaluate the technical status and economic feasibility of such systems.

We cannot help but note that the programs are managed by a skeleton staff of dedicated individuals. We would suggest that to have a credible program you need to have a credible management structure. That would suggest the Congress and the Administration seriously consider strengthening the staffs to a level sufficient to manage the programs that they have undertaken.

In summary, the Administration and the Congress must not lose sight of the hard facts of research: from the inception of the research program to the commercial viability, a project may take at least 10-15 years to complete. We must be working today for systems to be available for commercial use in the next decade.

The Electric Energy Systems and the Energy Storage Programs are both concerned with crucial development that will require such lead times and continuity of funding through the whole R&D cycle to achieve these goals. While we sincerely appreciate the recent willingness of the DOE administration to rededicate the government to working with the private sector to help solve these pressing problems, we believe additional funds should be allocated to these programs.

Events take place daily that clearly show the energy crisis of the 70's can easily recur with its economic chaos. We must advance our energy system options to be better prepared to withstand pressures brought to bear by radical forces in the world. We are entering into a more vital period in our history. It is essential that we move back to adequately funding the applied research and development programs in electrical technologies so that they will be ready when called upon to respond to the needs of the nation.

WILLIAM E. FEERO

Mr. Feero received his B.S. degree from the University of Maine, a M.S. degree from the University of Pittsburgh, and the E.E. degree from the Massachusetts Institute of Technology, all of which are in electrical engineering. He is a registered Professional Engineer in Maine, Pennsylvania and Virginia. He has published numerous technical papers and research reports.

Mr. Feero is president of Electric Research and Management (ERM), a company specializing in power delivery systems analysis. Areas of expertise include transient analysis, relaying systems and electric field analysis for bio-effects studies. In ERM he is responsible for conducting and managing projects concerning the generation, transmission, and distribution of electrical energy.

Before forming ERM, he was the program manager of the Power Supply Integration program of the Division of Electric Energy Systems of the Department of Energy (DOE), Washington, DC. The program provided for the timely and orderly integration of new source tecnologies into existing power systems. The program contained the Systems Engineering Section, the Load Management Section and the Dispersed Generation and Storage Section.

In 1976, Mr. Feero began his government service with the Division of Electric Energy Systems of ERDA (which became a part of the DOE) as Chief, Overhead Transmission Branch. Functional duties of the branch included research on overhead transmission lines and major substation apparatus. An important part of the program was an extensive study of electric field effects on transmission lines. Also, significant research on 1200 kV GIS apparatus and new transmission designs were sponsored by this branch.

Prior to government service, from 1972 to 1976, he was manager of the Transient Analysis Section of Westinghouse Electric Corporation, East Pittsburgh, PA. In this capacity, he was responsible for all ANACOM studies, switching surge field testing, digital transient program developments, and subsynchronous investigations. Also included in his area of responsibility were all Westinghouse studies of transmission line corona effects. This included operations of the Apple Grove, WV 765 kV test line facility.

From 1960 to 1972 Mr. Feero was involved in various system analysis functions at Westinghouse. Two of the most notable were transient studies and relaying studies using a digital computer coordination technique. The transient studies involved conducting in-depth studies of transient phenomena in power systems using both the ANACOM and digital techniques. The relaying work started as a Westinghouse task force effort to develop a computer program to select, coordinate and check both phase and ground relays. The successful results of this development were applied to studies of the relaying requirements of electric utility systems in most of North America.

Professional Society activities include:

Member CIGRE; Senior Member IEEE; Member T&D Committee; Member General Systems Subcommittee and Working Group on Switching Surges; Chairman of Working Group on Biological Effects of Power Frequency Electric and Magnetic Fields; Member of the Power System Relay Committee; Consumers Relaying Coordination Subcommittee; Relaying the Consumer-Utility Intertie Working Group Consumer; Owned Sources of Generation, 3000 KVA or Less Working Group; Relay Electric Environment Subcommittee; Chairman of the Electromagnetic Pulse Working Group.

Mrs. LLOYD. Thank you very much, Mr. Feero, for your very fine statement.

I think that we have all agreed here that we should give priority to the technologies that affect our economic well being as well as the security of our nation, and that it should be our long-range, high-risk research. We certainly recognize that industry does have limitations on their capital investments.

I would like to commend you for the very fine work that you are doing as well as your very fine statements.

Basically, in addition to the funding levels—I have this question for all of you—what are the main problems that you observed in the DOE's administration of these programs? I am not talking about the basic dollars at this point.

Mr. Feero, would you like to comment?

Mr. FEERO. Well, speaking on behalf of the Institute, I can't really make comments. We try to stick pretty much to the technological issues and not get into administrative detail.

The point of our whole concern, and really maybe to answer your question, is the lack of resolve to stay with solving problems.

Mrs. LLOYD. The inconsistencies of the programs, the up and down on the budgetary cycles?

Mr. FEERO. Exactly. They are extremely wasteful of capital resources and they are extremely wasteful of people. You get people geared up to go for a subject, and then you pull the rug out from under them.

Mrs. LLOYD. Yes, and I think it also destroys the confidence of the private sector in dealing with the Federal Government. I think we see this in our defense budget as well as the budget that you are concerned with. A lot of our overhead is involved with not knowing what the stop and start policy of our Government is.

Of course, for economic reasons, there is a tendency that you have to have some security built into your proposals, as well.

What comments would any of you like to add regarding the staffing levels of these programs? I think all of you have alluded to this just a little bit. I would like you to further elaborate on the staffing levels.

Mr. HELFRECHT. If I could just mention, from one standpoint, Madam Chairman, the staffing, of course, has been severely impacted by the fluctuations in the funding through DOE, particularly with this University of Wisconsin project. It is to the great credit of the University that they have been able to be flexible in that regard. However, as a consequence, there is no question but what they have lost certain of their scientists. I think that is what happens throughout our country in this regard.

When these programs are, in fact, cut back, and maybe appropriately so that some changes have to take place, but they have to take place in an orderly manner or we just have our entire scientific community in a total state of chaos. In the particular case of this effort, we have even lost people out of our country. They have gone to Great Britain. They have gone as far away as Egypt and the Far East.

Mrs. LLOYD. I think this is truly a national tragedy——

Mr. HELFRECHT. That is correct.

Mrs. **Lloyd**. That we are not only not funding adequate levels for scientific advancement, but we are losing so many great scientists. I think also we are not providing the proper incentives to encourage more young people to use their minds, as they say.

Mr. Endahl?

Mr. **Endahl**. I would like to comment that I have been impressed over the years with the desire of the DOE staff and the EPRI staff to work together on research projects. I think this is an excellent example of cooperation.

However, I think the DOE staff is severely limited by the things that you have just mentioned, the inconsistency of the budget, the programs that they can look forward to completing down the road 2 and 3 years. That is the biggest issue, I believe.

Mrs. **Lloyd**. Wouldn't you all agree that somebody's ears must be burning at OMB right now? [Laughter.]

Dr. Kalhammer?

Dr. **Kalhammer**. We have worked, as I said in my testimony, extremely closely with the DOE staff for a long time. I must tell you that I have truly the highest regard for the effort that the DOE staff has made to keep programs going, to adjust to changes in philosophy, and to work with us so that, between us, in an overall coordinated sense, through a rearrangement of the roles, the important programs could move forward. I have really the greatest respect for our colleagues at DOE. They have also made, I think, quite creative and proper use of national laboratory people where they have various project management centers that have been very helpful and continue to play an important role. These are people with whom we also have liaison and access to.

There is no question that the DOE staff is thin. I think they are doing an exceptional job given the levels of staff that they have.

Our biggest concern is also the one that has been voiced by the other panelists, and that is the continuity of the programs. Our position tends to be flexible so that, from an overall national standpoint, continuity is maintained.

Mrs. **Lloyd**. Mr. Helfrecht, would you review for us a little further the current perspective on the economics of a large scale SMES?

Mr. **Helfrecht**. The economics is demonstrated by the study which EPRI just completed last July. They give the indication that at the present state of the art, that is, the state of the design of the device, SMES could be competitive with our midrange coal fired generation which is commonly in the neighborhood of about $1500 to $2000 per kW, and this device is believed to be presently about $1300 per kW. With further research, which everybody agrees is appropriate and necessary to define certain aspects, it is believed that this can be reduced down into the neighborhood of $900 kW which then says it is highly competitive with the cycling type of coal.

The study we have completed for our companies indicates that the marketplace then says that if we are able to store energy in this device that is produced on lower cost equipment and keep the high cost equipment off during the day that it will be a significant economic advantage to the utilities that would install such a unit.

Mrs. LLOYD. Would any of you other panelists care to comment on the potential for SMES?

Dr. KALHAMMER. Since Mr. Helfrecht has referred to the EPRI study and since there have been a fair number of evaluations at EPRI of this technology, I feel that I probably should make these comments briefly.

We certainly would agree with the view that from the point of view of the technology and its functional aspects, SMES is both the most efficient and the most direct way of storing electric energy. I think there can be little doubt about it.

The current question that surrounds SMES is economics. Can it be competitive? Mr. Helfrecht pointed out that it could be competitive with cycling coal plants, and again we would certainly tend to agree if it can actually be built at the costs that are now essentially the results of the conceptual design studies. The other comparison that is inevitable here is the one with other energy storage devices, whether that would be compressed air storage or batteries or perhaps underground pumped hydro. It is our evaluation at this point that if SMES is to become competitive with other energy storage options, the kind of advances that Mr. Helfrecht alluded to and that would result in lower costs—and these are both design improvements and reduction of materials costs which play a big role in SMES—must occur. For that to occur, some further research is clearly indicated.

We at EPRI have a rather small, very modest effort in this area. We do tend to believe on the basis of the assessments that we have and conducted for us by very competent people, including the University of Wisconsin, that the advances have to be fairly basic and that perhaps the best potential is in the materials area. So, we feel that this is more of an R&D issue and not a developmental proposition at this time, and we tend to think of SMES as a technology for the longer term, the year 2000, roughly speaking.

I think that is what I can contribute.

Mrs. LLOYD. Further comments?

Dr. Kalhammer, we had discussed, mainly with the witnesses from DOE, the real marketability of our advanced battery systems. What impact do you feel that this successful technology could have on our economy? What is the impact of this technology?

Dr. KALHAMMER. I think we probably have to be somewhat specific about the applications. When you talk about the battery development effort of DOE, it really has 2 targets. One of them is the stationary application for electric utility energy storage, and the other one is for electric vehicles. Let me take them one by one.

I am probably somewhat more familiar with the electric utility storage area because this is a big focal area at EPRI, and we have to ask ourselves very similar questions. We have done, over the years, a series of market assessments of how much energy storage might be usefully added to electric utility systems in this country. There is little question in our mind that, even conservatively speaking, the potential for energy storage is several 10,000's of megawatts. If you want to convert that into economic potential, you have to realize that, let's say just to pick a number, 20,000 megawatts would be 20 million kilowatts, and since energy storage systems typically would cost on the order of $500 per kilowatt, you can multiply 20 million times 500. If I calculated that right it is $10 billion. So, you do have potentially a $10 billion industry to build these storage systems. That is one way of looking at it.

The other way of looking at it, of course, is in terms of how much oil would be displaced. We are talking here of many, many millions of barrels per year. Fundamentally, each energy storage system that would have, say, 1,000 megawatt capacity could displace in the order of about a million barrels per year. Clearly, that is a very significant impact.

Now, if I can just prolong this comment for a moment and address a point that you raised with the DOE panel, there is the question, of course, when will such an industry materialize and what are the barriers to that? My response to that question would be that energy storage for electric utilities, particularly if it is batteries, for instance, will be an entirely new way of doing a job. Electric utilities tend to be conservative. They tend to rely on equipment that they know works well, has establishd reliability and operating characteristics. You are going to have to go pretty far in terms of demonstration and first of a kind systems before the electric utilities, the first one will step forward and say we are going to try this. They also have to convince their commission to share the risk essentially.

As long, then, as there is not a clear market held out by great utility enthusiasm, any manufacturer will have serious doubts as to whether a market for a new technology really exists. So, you have a little bit of a vicious cycle or chicken-and-egg story here. You have to show that the technology works and that requires investment, not only in research but also in demonstration, but as long as there isn't a willing customer out there, the private sector is having trouble making this kind of investment.

I think what you have to do is take it step by step. Try to push the R&D, use organizations like EPRI to participate in demonstrations, try to get some cost sharing from the manufacturers in which both DOE and we have been successful, and then hope that the utilities will start committing and encourage developers to put in the production facilities.

That is a long answer to your question.

I think the electric vehicle situation is not at all unlike that but perhaps even more complicated because you are dealing with a large industry that would have to change and make investments in a new product that competes with their existing product, and there need to be a number of driving forces here for that to occur. Nevertheless, from a national interest point of view, I think it is important that the Department push the electric vehicle application and batteries for it.

Mrs. **Lloyd.** So basically for national security, we need to have the technologies in reserve even though they are not ready for the marketplace and the marketplace is not looking in their direction at the present time.

There are other questions I want to ask you——

Mr. Endahl, go ahead.

Mr. **Endahl.** With respect to battery storage, I think Dr. Kalhammer has given you a good answer, but I think the market is closer than maybe we expect. There are limits in the amount of energy that can be controlled with the typical load management schemes, and that would be an ideal use for the load-leveling battery system.

Mrs. LLOYD. Thank you very much.

I really appreciate the benefit of your wisdom. There are other questions I wanted to ask you, but we do have time constraints this afternoon. I hope that you will agree to questions that we will submit in writing for the record.

Thank you very much for being with us.

Our next panel includes Mr. Roger Carlsmith, who is Director of the Conservation and Renewable Energy Program at Oak Ridge National Laboratory; and Dr. Elton J. Cairns, Associate Director, Lawrence Berkeley Laboratory; and Dr. Roger Boom of the Nuclear Engineering Department of the University of Wisconsin.

We welcome all of you here today. We're very happy to have you with us. And if you will, proceed with your testimony. You may proceed, Mr. Carlsmith. We're happy, awfully happy to have you with us today.

STATEMENT OF ROGER CARLSMITH, DIRECTOR, CONSERVATION AND RENEWABLE ENERGY PROGRAM, OAK RIDGE NATIONAL LABORATORY, ACCOMPANIED BY DR. ELTON J. CAIRNS, ASSOCIATE DIRECTOR, LAWRENCE BERKELEY LABORATORY; AND DR. ROGER BOOM, NUCLEAR ENGINEERING DEPARTMENT, UNIVERSITY OF WISCONSIN

Mr. CARLSMITH. Thank you, Madam Chairman. It is a pleasure to be here.

I would like today to discuss with you some of the research we are doing at the Oak Ridge National Laboratory. Our program at ORNL includes conservation projects aimed at improving the energy efficiency in all sectors.

We have approximately 110 scientists and engineers assigned to conservation. In addition, we subcontract much of the work to universities and industry. Frequently, the subcontracts with industry include cost sharing between DOE and the industrial participants.

I will discuss the two areas of the ORNL conservation program which come under the jurisdiction of this subcommittee. These are the power systems technology project, funded by the DOE Division of Electric Energy Systems; and thermal energy storage, funded by the DOE Division of Energy Storage.

The power systems technology program addresses three main issues: First, reliable electricity supply; second, health and safety; and third, conservation and resource management.

A reliable electric network is required for a healthy economy and for service to continue during all sorts of emergencies. Although present electric utility systems are very reliable, the cost of system failures is prohibitive and is borne mainly by the general public.

Private sector R&D is limited because of the long-term costly commitment required. The private sector will implement new concepts only after they are proven to be technologically sound.

Of particular concern in health and safety are the effects of exposure to electric fields from electric power transmission. Public concern over suspected effects is delaying expansion of the high-voltage network in a number of places. Basic research is required to determine the effects and provide the utility industry with data for design guidelines.

Electric utility systems' losses amount to nearly 10 percent of all generated power, as is well known. Similar losses are attributed to industrial motors and transformers. Thus, there are large savings in energy and moneys that can be obtained through better technologies.

To illustrate the research at ORNL on these three main issues, I will describe a few of our research projects.

One of the most significant is the Athens automation and control experiment in Athens, Tenn. This experiment is being conducted in cooperation with the Athens Utility Board, TVA, and the Tennessee Valley Public Power Association. The Electric Power Research Institute has also recently joined the effort.

The primary goal of the project is to show by experiment the benefits of improving the basic operating efficiency of electric distribution systems. To do this, a computer-based control center will be installed. This center will allow the operator to monitor and manage the distribution network on a minute-by-minute basis. By programing the control center, various methods for automated operation will be tested and evaluated.

This large-scale project will answer many questions regarding the potential for using demand-side management to improve the operation of electric systems.

We have conducted a series of studies to determine the best way to operate a utility system which contains dispersed power sources, such as photovoltaic, wind, waste heat, and cogeneration. The purpose of these studies was to determine the adequacy of the utility industry's traditional practices when alternative energy sources are present.

We conclude that only minor changes are needed when the dispersed power sources are a small part of the total system. However, harmonic distortion must be reduced, and utilities may need to modify some operating practices.

In the longer term, greater amounts of dispersed power will demand a control system similar to the one to be installed in the Athens automation and control experiment.

We are also developing new materials to improve transmission and distribution of power. One new material will be used to produce a more compact and versatile varistor. Varistor is the name given to massive ceramic devices that are used in high-voltage switchyards to handle overloads from lightning and other surges. However, the size of present commercial varistors, up to 40 feet in length, has made them difficult to use in congested urban areas. The ORNL development, which significantly reduces the size of the grains in the constituent ceramic material, produces a varistor that is 10 times smaller.

In addition to possible cost reductions, this development can possibly be used in underground transmission lines operating at extremely high voltages.

A strong electromagnetic pulse, which is called EMP, will result from the detonation of nuclear weapons. The consequences of EMP on electric power systems are unknown but are suspected to be devastating. Efforts are underway to develop a quantitative understanding of the potential effects and methods that might be used to protect the power systems.

The research includes simulation models, assessment methodologies, and protection hardware. Technologies developed in this activity will also be applicable to the problem of protecting power systems from other disturbances, such as sabotage or accidental malfunctions.

However, an important difference between an EMP disturbance and other major disturbances is that the effects of EMP would be distributed throughout the power system, whereas many other disturbances are localized.

Thus, the DOE reliability program is strongly focused on EMP.

I will now turn to a second area of ORNL research. ORNL has managed portions of the DOE's thermal energy storage program from the program's inception in 1976. Several successful systems have been developed. Examples include polyethylene beads which are partially polymerized by electron beam irradiation and are used for solar energy storage.

The Dow Chemical Co. has developed a product called Thermal 81 under ORNL subcontract. This product, which uses encapsulated rods to store heat, is now sold widely by Dow for use in solar systems.

The Pennwalt Corp. is marketing encapsulated salt hydrates based on DOE ORNL development.

The present program covers two major areas: First, electric utility load management applied to the heating and cooling of buildings; and second, utilization of industrial waste heat which would otherwise be lost.

Development of storage technologies that can be used with heating and cooling systems will permit utilities to shift part of their loads from peak times to low-usage times. Thus, successful development will enable utilities to meet a greater fraction of their load by economical base-load generating equipment.

An additional benefit would be reduce the need for new powerplants. More widespread capture and reuse of industrial waste heat by thermal storage systems will also produce substantial energy savings. ORNL studies have shown, for example, that energy consumption in brick kiln operations can be reduced 45 percent through the use of a heat storage system.

Our search for an ideal storage medium for heat pumps and air conditioners has led to the examination of clathrates. These substances are composed of two materials in which molecules of one type are enclosed by a crystalline lattice or cage of molecules of the second type.

It has been shown, for instance, that water and the refrigerant R-12 form a clathrate at a temperature of 53° F. This temperature is ideal for a storage system to be used with an air conditioner. The elevated freezing temperature allows warm ice to be made, increasing the efficiency of the air conditioner. Preliminary experiments have already shown that the storage system can be made to function, and an experiment with a complete heat pump or air conditioner is being designed.

In another project, a series of high-temperature latent heat storage materials suitable for industrial applications is under development through a subcontract with the Institute of Gas Technology. This concept involves the retention of a molten salt within the porous microstructure of a sintered ceramic body. The composite medium can be used in direct contact with heat transport fluids. Direct contact reduces costs by eliminating intermediate heat exchangers and also enhances the temperature of the recovered energy.

The next step in this development is to use the material in an operating environment closely approximating the conditions of an industrial application.

Scientists at the Pacific Northwest Laboratory and the Lawrence Berkeley Laboratory have also been conducting a systematic search for other materials that meet the criteria for thermal energy storage. Exploratory research is now being conducted on a few of the most promising candidates. Although it is not possible to predict which of these candidates will eventually prove to be the most useful, the large amount of energy now going to waste gives strong incentive to find ways to recover some portion of it. Improved thermal energy storage technologies offer excellent prospects for reducing this waste.

That will conclude my statement. Thank you very much.

[The prepared statement of Mr. Carlsmith follows:]

ORNL RESEARCH PROGRAMS

on

Power Systems Technology and Thermal Energy Storage

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Testimony to the
Subcommittee on Energy Research and Production
Committee on Science and Technology,
U.S. House of Representatives

Hearing on the FY 1985 Authorization for the
Department of Energy's Conservation
Research and Development Programs

March 7, 1984

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It is a pleasure for me to be here today to discuss with you some of the research we are doing at the Oak Ridge National Laboratory (ORNL) for the Department of Energy. Our program at ORNL includes projects aimed at improving the efficiency of energy use in all sectors of the energy economy: residential, commercial, industrial, transportation, and electric utilities. Approximately 110 scientists and engineers from the ORNL technical staff are assigned to the program. In addition, we subcontract substantial portions of the work (about 55%) to universities and industry in order to obtain experts in each field and also to obtain the involvement of industry at an early stage of the research. Frequently, the subcontracts with industry include provisions for cost sharing between DOE and the industrial participant.

I will discuss today the two areas of the ORNL Conservation Program which come under the jurisdiction of this Subcommittee. These are Power Systems Technology, funded by the DOE Division of Electric Energy Systems, and Thermal Energy Storage, funded by the DOE Division of Energy Storage.

The Power Systems Technology Program is applied research, that is, research to advance the technology in the country's electric power network. The program addresses three main issues: (1) reliable electricity supply, (2) health and safety, and (3) conservation and resource management.

A reliable electric network is required for a healthy economy and for service to continue during all types of emergencies, both civil and military. Although the present electric utility systems are very reliable, the cost of system failures is prohibitive and is borne mainly by the general public. Economic pressures on utilities require more electrical power at acceptable reliability and capital expenditure levels. Private-sector R&D is limited because of the long-term, costly commitment required to advance the state-of-the-art. The private sector will implement new concepts only after they are proven to be technologically sound. The intent in developing a reliable electric supply is to have an electrical network that will enhance regional energy exchanges, optimize controllability of all electric energy sources, and improve continuity of essential services, especially during emergencies.

Of particular concern are the possible health and safety effects from exposure to electric fields arising from electric power transmission. Public concern over suspected effects is delaying expansion of the high-voltage electric network in a number of places. Basic research is required to clarify issues, determine the threshold of effects, and provide the utility industry with data for design guidelines. The objective of government research is to determine safe threshold levels below which the health risk is within acceptable limits. The efforts focus on biological research, direct-current ion propagation, and risk assessment for human exposure.

Electric utility system losses amount to nearly 10% of all generated power. Similar losses are attributed to industrial motors and transformers. Thus, large savings in energy and money can be obtained through better technologies. Further, with the economical use of energy storage and resource management, fuel switching (substitution of coal, nuclear, and renewable resources for scarce, expensive fuels) can be achieved economically. Research is needed to develop advanced materials, technologies, and control systems.

To illustrate the research at ORNL on these three main issues, I will describe a few our research projects. One of the most significant is the Athens Automation and Control Experiment in Athens, Tennessee. This experiment is being conducted in cooperation with the Athens Utility Board, TVA, and the Tennessee Valley Public Power Association. The Electric Power Research Institute has also recently joined the effort. The primary goal of the project is to show by experiment the benefits of improving the operating efficiency of electric distribution systems. To do this, a computer-based distribution control center will be installed. This center will allow the distribution system operator to monitor and manage, on a minute by minute basis, the distribution network and residential customer energy consumption. By programming this control center, various methods for the automated operation of the distribution system will be developed, tested and evaluated. This large scale project will answer many questions regarding the potential for using demand-side management to improve the operation of electric systems.

We have conducted a series of studies to determine the best way to operate a utility system containing dispersed power sources. Dispersed power sources include photovoltaics, wind, waste heat, and cogeneration. The purpose of the studies is to determine the adequacy of the electric utility industry's traditional practices, equipment, and design when alternative energy sources are present. We conclude that only minor changes in safety practices and protection devices are needed when the dispersed power sources are a small part of the total system. However, harmonic distortion associated with dc to ac conversion of electric power must be reduced, and electric utilities may need to modify some operating practices such as the use of power factor correction capacitors. In the longer term, greater amounts of both small and large dispersed power devices will demand an automation system similar to the one to be installed in the Athens Automation and Control Experiment.

We are also developing new materials to improve transmission and distribution of power. One new material will be used to produce a more compact and versatile "varistor." Varistor is the name given to the massive ceramic devices used in high voltage switchyards, transformers, and transmission lines to handle overloads from lightning and other surges. However, the size of present commercial varistors - up to 40 feet - has made them difficult to use in congested urban areas. The ORNL development, which significantly reduces the size of the constituent grains in the ceramic material, produces a varistor ten times smaller. In addition to possible cost reductions, this development opens the possibility of use in underground transmission lines or in energy-saving gas-insulated structures operating at extremely high voltages.

A strong electromagnetic pulse (EMP) will result from the detonation of a nuclear weapon. The consequences of EMP on electric power systems are unknown but are suspected to be devastating. Efforts are underway to develop a quantitative understanding of the potential effects and methods that might be used to protect electric power systems from EMP. The research includes simulation models, assessment methodologies, experimental methods and data, protection hardware, and special operation and control procedures for electric power systems. Technologies and systems developed in this activity will also be applicable to the problem of protecting power systems from other disturbances, such as sabotage or accidental malfunctions. An important difference between an EMP disturbance and other major disturbances is that the effects of EMP would be distributed throughout the power system whereas many other disturbances are localized. Thus, the DOE program on electric system reliability is strongly focused on EMP.

I will now turn to a second area of ORNL research. ORNL has managed portions of the DOE Thermal Energy Storage Program from the program's origin in 1976 under ERDA. Several successful systems have been developed. Examples include polyethylene beads which are partially polymerized by electron beam irradiation and are used for solar energy storage. The Dow Chemical Company developed a product called Thermal 81 under ORNL subcontract. This product, which uses encapsulated rods to store heat, is now sold widely by Dow for use in solar systems. The Pennwalt Corp. is marketing encapsulated salt hydrates in a range of phase change temperatures, based on DOE/ORNL developments.

The present program covers two major areas of national importance: electric utility load management applied to the heating and cooling of buildings and utilization of industrial reject heat which would otherwise be lost. Development of storage technologies that can be used with heat pumps will permit utilities to shift part of their loads from peak-usage times to low-usage times. Thus, successful development will enable utilities to meet a greater fraction of their load by economical, base-load generating equipment. An additional benefit will be to reduce the need for new power plants. More widespread capture and reuse of industrial waste heat by cost-effective, thermal storage systems will produce substantial energy savings. ORNL-sponsored studies have shown, for example, that energy consumption in brick kiln operations can be reduced 45% through the use of a heat storage system.

Our search for an ideal storage medium for heat pumps has led to examination of clathrates. These substances are composed of two materials in which molecules of one type are enclosed by a crystalline lattice or cage of molecules of the second type.

It has been shown experimentally at ORNL that refrigerant R-12 (CCl_2F_2) and water, under suitable conditions, form a gas clathrate at a temperature of 12°C (53°F) with a heat of formation comparable to that of ice. This temperature is ideal for a storage system to be used in conjunction with an air conditioner. The elevated freezing temperature allows "warm ice" to be made, increasing the efficiency of the air conditioner. Preliminary experiments have already shown that the storage system can be made to function, and an experiment with a complete heat pump or air conditioner is being designed.

As a generic type, clathrates offer the potential for dual-temperature operation - storage of cool for summer and heat for winter. Efforts in this area are concentrated on identifying compatible materials that will form clathrates over the temperature ranges 5-15°C and 32-50°C, with one of the materials being a condensible vapor that can be used in the heat pump cycle.

A series of high-temperature latent heat storage materials suitable for direct contact heat transfer for industrial applications is under development through a subcontract with the Institute of Gas Technology. The concept involves the retention and immobilization of a phase change salt within the porous microstructure of a sintered ceramic body. Immobilizing the molten salt in this manner allows the composite medium, when fabricated into suitable shapes, to be used in direct contact with compatible heat-transport fluids. Direct contact reduces energy-recovery costs by eliminating intermediate heat exchangers and enhances the quality of the recovered energy by reducing temperature drops across heat exchanger tube walls. The next step in this development is to use the material in an operating environment closely approximating the conditions in an industrial application.

Scientists at the Pacific Northwest Laboratory and the Lawrence Berkeley Laboratory have also been conducting a systematic search for other materials that meet the criteria for thermal energy storage. Exploratory research is now being conducted on a few of the most promising candidates. Although it is not possible to predict which of these candidates will eventually prove to be most useful, the large amount of energy now going to waste gives strong incentive to find ways to recover some portion of it. Improved thermal energy storage technologies offer excellent prospects for reducing this waste.

ROGER S. CARLSMITH

Biographical Sketch

Mr. Carlsmith received his education at Harvard University (B.S. in Chemistry) and at the Massachusetts Institute of Technology (M.S. in Chemical Engineering). Since 1955, he has been a member of the research staff of the Oak Ridge National Laboratory (ORNL) and has participated in a wide variety of energy development programs. These have included research on the design and economics of advanced nuclear reactors, analysis of environmental effects of energy production, and research on the factors influencing energy demand. Since 1970 he has directed research activities related to energy efficiency and energy conservation.

Mr. Carlsmith is currently Director of the Conservation and Renewable Energy Program at ORNL.

Mrs. **Lloyd**. Thank you very much for your very fine statement. Dr. Cairns.

Dr. **Cairns**. Good afternoon, Madam Chairwoman, members of the subcommittee. I am Elton Cairns, associate director of Lawrence Berkeley Laboratory and professor of chemical engineering at the University of California, Berkeley. Thank you very much for the opportunity to present my views on the very important topic of energy storage.

Mrs. **Lloyd**. We're delighted to have you here.

Dr. **Cairns**. The U.S. Department of Energy and its predecessor agencies have supported an energy storage R&D program since the 1960's. The aim of this program has been to provide advanced energy storage and conversion systems that will shift a significant portion of our demand away from petroleum and toward the more available domestic fuels such as coal, nuclear, and renewable energy sources, as well as to provide efficiency improvements for energy-intensive processes.

These objectives would be achieved with an environmental impact significantly more benign than that of our current practice.

Energy storage systems have the important ability to decouple the variations of energy supply from those of energy demand. This feature offers a greater choice of energy sources. For example, electrical energy storage in high-performance batteries makes possible the use of electric vehicles, thereby shifting a portion of our transportation energy demand away from petroleum toward coal, nuclear, and hydroenergy.

Energy storage in electric utility systems provide for operation of expensive powerplants at a steady high-power level, charging the storage system during offpeak periods. During peak demand periods the storage system provides part of the power, avoiding an investment in powerplants sized to meet the maximum or peak power demand.

Because emissions from energy storage devices are nil, the emissions control problem is shifted away from these devices to the central powerplant where it is much more readily controlled.

The potential financial benefits to this country that can result from the development of advanced energy storage and conversion devices are massive. Substitution of domestic energy resources for imported petroleum will improve the U.S. financial and strategic position. For example, the use of battery-powered electric vehicles could result in the reduction of petroleum imports by over 400 million barrels of oil per year. This oil import costs $12 billion per year at present prices. Avoidance of this import would be a significant improvement in the balance of payments.

Capture of the future national and international market for energy storage systems will improve the competitive commercial position of the United States. A new multibillion-dollar per year energy storage industry would arise. The existing DOE energy storage program has focused upon the following end-use sectors: Advanced batteries for electric vehicles, energy storage for electric utilities by means of thermal energy, storage batteries, and superconducting magnetic energy storage, and thermal energy storage systems for use in buildings and industry.

This program bridges the gap between fundamental research usually performed at universities and product development performed by industry. The most promising energy storage systems undergo applied research, exploratory development, and testing, followed by technology transfer to the private sector.

Some of the most promising electrochemical systems from the viewpoint of performance, durability, and potential cost represent significant achievements of the DOE program. Following are some examples:

The sodium/sulfur battery is a high-performance, high-temperature system that uses abundant low-cost active materials. The costs and life of the ceramic electrolyte must be improved to meet the demands of both stationary and mobile applications. Several years of additional R&D are necessary before commercial development is viable. Impressive performance results have been obtained with test batteries up to 100 kilowatt hours of energy storage capability. It is important that the United States maintain its lead over foreign competition in this promising technology.

The lithium/metal sulfide battery also operates at elevated temperatures and provides high performance and long life. It is an early stage of development and promises to be a very robust system. Recent cell tests have demonstrated lifetimes of about 1,000 charge-discharge cycles, a very significant achievement.

More work on low-cost construction materials and multicell module engineering is needed.

Alkaline batteries under DOE sponsorship have advanced to significantly higher performances and longer lives. Test batteries have been operated both at the National Battery Testing Laboratory, a DOE facility at Argonne National Laboratory, and in electric vehicles. Alkaline systems offer greater electrical vehicle range between recharge and higher vehicle performance than lead-acid batteries.

Zinc/bromine and zinc/chlorine batteries could prove to be very useful, especially in stationary applications such as electric utility networks. A particular advantage of these systems is their projected low cost, below that of lead-acid batteries. Materials research, system complexity, and halogen safety require additional effort. With continued support, the zinc/chlorine system will complete its tests in the battery energy storage test facility, and the zinc/bromine system can be similarly tested at the 500-kilowatt-hour level within the next few years.

Metal/air batteries that use aluminum, zinc, or iron as the fuel in combination with oxygen taken directly from air may prove attractive for electric vehicles. They can be refueled by adding more metal, and the zinc and iron systems offer the option of electric rechargeability. The key remaining problems are: durable, high-performance, low-cost air electrodes; system complexity; efficiency; and cost.

Fuel cells, which have been very successful in space applications, can be modified to provide an efficient hydrogen-fueled electric power source for vehicle propulsion. The hydrogen gas can be prepared on the vehicle from easily stored liquid fuels such as methanol or ammonia. This would provide an efficient electric vehicle that is refueled as rapidly as conventional automobiles. The R&D

needs of these systems include: higher performance, lower cost, longer life, reduced startup time, and better transient response. These electrochemical systems have many important scientific and technical elements in common, and advancement of this field is provided by a strong DOE technology base research program which provides new systems, new materials, and new knowledge for improvement of the technology.

In the area of physical and chemical energy storage technologies, current important activities include: thermal energy storage in clathrate compounds, thermal energy storage by means of reversible thermochemical reactions, solid-state radiative heat pumps for use with thermal energy storage systems, phase-change materials for thermal energy storage, and hydrogen production and storage for chemical energy storage uses. Recent results on high-temperature water electrolysis have demonstrated higher efficiencies than the lower-temperature systems.

In addition to the achievements just mentioned, an important element of Government-sponsored R&D is the transfer of technology to the commercial sector. The DOE program has been successful in this area, as evidenced by the following examples:

A new air electrode has been developed for energy savings in chlorine/caustic cells. In the short period of 4 years a cooperative DOE-industry-university program has developed an air electrode which yields a very significant one-volt reduction in cell potential. Eltech Systems, Inc., is pursuing this technology for alkali industrial application.

Under DOE sponsorship, Gould, Inc. has developed a novel sealed lead-acid battery which is now being commercialized by Gould.

Hydrogen production by a simple polymer electrolyte system has been developed and demonstrated in the DOE program and is being commercialized by General Electric.

A prototype chemical heat pump for use with thermal energy storage systems has been developed and is being investigated by the private sector for use in sulfuric acid concentrators.

A superconducting magnetic energy storage system was built at Los Alamos National Laboratory and is now being tested by Bonneville Power Administration.

From these examples, it can be seen that the DOE energy storage program is a vigorous, coordinated program and is pursuing appropriate advanced energy storage systems with proper attention to technology transfer. The future prospects for even greater advances are bright with continued healthy funding levels. Since there is no single energy storage system that will clearly be appropriate for all intended applications, it is necessary to continue with a balanced, moderately diversified program until clear winners are identified for the important applications for both stationary and mobile energy storage.

The recent funding level of $25 million per year is extremely modest in comparison to the estimated multibillion-dollar-per-year market and associated balance-of-payments benefits to this country. In order to bring a single energy storage system to the stage of realistic test hardware, a funding level of 1 to 5 million per year is needed. At this point, there are several systems worthy of pursuit. In addition, the technology base research effort is strongly needed to support the development activity. Altogether, this would mean about $40 million per year for energy storage systems of all types. This is a very modest amount, considering the potential benefits.

Thank you very much for your attention.

[The prepared statement of Dr. Cairns follows:]

THE NEED FOR A VIGOROUS DOE ENERGY STORAGE PROGRAM

by

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and

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March 7, 1984

ABSTRACT

The DOE energy storage program has led the U.S. effort to develop advanced energy storage and conversion systems. Successful development of one or more systems would result in tremendous economic and strategic benefit to the United States. This document describes the energy storage program, outlines recent progress and future prospects, justifies continued federal support, and indicates an appropriate funding level.

THE NEED FOR A VIGOROUS DOE ENERGY STORAGE PROGRAM

Introduction

The U.S. Department of Energy and its predecessor agencies have supported a coordinated program to develop energy storage technologies since the 1960s. The primary aim of this program is to provide advanced energy storage and conversion systems that will: (a) permit the substitution of coal, nuclear and renewable energy resources for petroleum-based fuels, and (b) improve the efficiency of energy-intensive processes. These objectives would be achieved with an environmental impact significantly more benign than that of our current practice. This document describes the content and scope of the DOE Energy Storage Technologies Program, assesses recent progress and future prospects, and identifies and justifies an appropriate level of federal funding to ensure a reasonable probability of success.

Background

Energy storage systems have long been recognized for their ability to decouple energy supply from energy demand, a feature that offers valuable flexibility in the choice of fuels and energy sources. For example, electrical energy storage in advanced batteries makes possible electric automobiles and vans that can serve the important purpose of shifting a portion of the transportation energy demand away from petroleum, and toward coal, nuclear, and other domestic energy sources. Electric vehicles are also attractive from an energy-conservation point of view, because they would consume substantially less primary (e.g. coal) energy than the equivalent vehicle powered by synthetic fuel. Electrical energy supply systems would also benefit by the use of energy storage as part of the system. Energy storage devices make possible the matching of the load with the energy supply (load-leveling), providing energy storage for periods of several hours to several days. Without energy storage, load following is either impractical (for nuclear) or impossible (for stand-alone wind and solar). Peaking power, which is presently provided by relatively inefficient, petroleum-consuming gas turbines, could be provided by energy storage systems. Because emissions from energy storage devices are either zero or very small, the emission control problem is shifted to the power plants where it is much more readily handled.

The development of viable means to produce, store, transport and utilize hydrogen could result in the substitution of this attractive fuel for petroleum (in vehicles) and natural gas (for heating). The implementation of advanced methods to store thermal energy would facilitate more efficient heating and cooling of buildings and permit the effective use of solar-thermal technology.

The potential benefits derivable from the development and implementation of advanced energy storage and conversion devices are massive:

- Substitution of domestic energy resources for imported petroleum will improve the U.S. financial and strategic position. For example, the development of advanced batteries suitable for electric vehicle propulsion could result in the reduction in U.S. petroleum consumption of more than 400 million barrels of oil per year (at $30/bbl, $12 B/y).

- Capture of the future international market for energy storage systems will improve the competitive position of the U.S. commercial sector. A new multi-billion dollar-per-year industry to produce energy storage devices would arise.

- Energy storage technologies will promote the utilization of renewable energy resources and centralized energy production systems, resulting in greatly reduced environmental damage.

The development of energy storage systems clearly supports the National Energy Policy Plan,* which calls for "a balanced and mixed energy resource system."

Description of the DOE Program

The major goal of the DOE energy storage program is to provide advanced storage and conversion technologies that can facilitate the substitution of domestic energy resources for imported petroleum and/or permit the more efficient utilization of domestic resources. The program has identified end-use systems, such as electric vehicles and electric load-leveling devices, that exhibit the potential for major petroleum saving if substantial penetration into commercial markets can be realized. Research and development efforts are therefore focused on storage and conversion systems that offer the attractive combination of high performance and low life-cycle costs necessary to compete with the existing petroleum-consuming energy conversion devices.

The energy storage program bridges the gap between fundamental research, traditionally performed at universities, and the corporate role of product development. The program is a coordinated, cooperative effort conducted at national laboratories, universities and corporate laboratories. The most promising systems undergo exploratory development and testing to the point where technology transfer to the private sector is appropriate. Technology-base research efforts to evaluate new systems, materials, and components, and to provide supporting research, are a vital part of the energy storage program.

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* October 1983

A number of promising energy storage and conversion systems have been developed under DOE sponsorship in recent years. Each has particular advantages as well as significant technical barriers. Within the electrochemical category, these systems are listed in approximate order of priority, considering their likelihood of meeting stringent performance, cost and efficiency requirements.

1. Electrochemical Systems

- The Sodium/Sulfur Battery

  Invented in the 1960s, this high-temperature battery system offers the potential of exceptional performance using abundant, low-cost active materials. The cost and life of the solid ceramic electrolyte need improvement to meet the demands of the intended stationary and mobile applications. Several years of research, especially in the area of materials science, are needed for this system.

- The Lithium/Metal Disulfide Battery

  This high-temperature battery system was invented by a national laboratory in the early 1970s, and is a candidate for both stationary and mobile applications. The key R&D barriers include development of a low-cost separator and higher-performance electrodes. The U.S. has clear worldwide leadership in this battery technology.

- Alkaline Batteries

  The most promising alkaline system is the zinc/nickel oxide battery. Its power capability and energy capacity are both outstanding, but present cycle life is inadequate. Fundamental research is required to achieve improved understanding of the life-limiting mechanisms -- this knowledge could lead to methods for improving the life of this system without compromising other attractive features. This battery is targeted for mobile applications but must be considered to be in the early development stage.

- Zinc/Halogen Batteries

  The zinc/chlorine and zinc/bromine systems are viable candidates for load-leveling applications and offer the promise of highly efficient energy storage at a low cost. System complexity and halogen safety are key R&D issues.

- Hydrogen Systems

  High-temperature water electrolysis systems have demonstrated electrical efficiencies superior to those obtained by conventional electrolysis systems, but costs are greater than those for existing hydrogen sources.

- Metal/Air Batteries

  Either aluminum, iron, or zinc can be used with an opposing electrode which consumes oxygen from the air. This feature is attractive because the air electrode eliminates the necessity of carrying part of the reactants in a mobile battery. The engineering and electrochemistry of a practical air electrode, either primary or rechargeable, is a key research project.

- Fuel Cells

  Fuel cells offer a highly-efficient means for utilizing hydrogen (produced on the vehicle from methanol or ammonia) and could be employed as a power source for "unlimited-range" electric vehicles. Primary limitations include system costs and response time to power demand transients.

2. Thermal Energy Storage Systems

   Development of advanced materials that exhibit sufficient stability and thermal efficiency could result in more efficient heating and cooling of buildings, and efficient storage of high-grade thermal energy for industrial processes. A number of new materials have shown promise.

3. Superconducting Magnetic Energy Storage

   This technology offers high efficiency for electrical load-leveling applications. High system costs must be reduced before commercialization can proceed.

Cross-cutting technology-base research studies, not listed above, include:

- Electrochemical phenomena: supporting research to provide better understanding of the complex phenomena that limit the performance and lifetime of electrochemical systems.
- New materials: supporting research aimed at the development of new components required to advance or improve energy storage technology.
- New systems: exploratory research on new electrochemical couples with the potential for higher performance and/or lower life-cycle costs than existing batteries. Ambient-temperature lithium, intermediate-temperature molten salt, hydrogen/nickel oxide, zinc/ferricyanide cells and thermally-powered cells are presently under evaluation.
- Battery testing and analysis: evaluation of the performance, life and failure modes of advanced prototype batteries under careful laboratory control.
- Electrochemical technology: identification of new, low-cost catalysts for electrochemical energy conversion systems.
- Corrosion research: applied research to mitigate corrosion processes that limit the lifetime of energy storage and conversion systems.

These cross-cutting activities support the development of all existing energy storage and conversion systems and provide the mechanism for introduction of new systems. As such, they are not prioritized along with the systems listed previously.

Recent Progress

Major advances in battery fabrication techniques and the development of new cell components have permitted the construction of large advanced battery systems. A 100-kWh Na/S battery (sufficient to provide load-leveling for a small commercial building) and a 20-kWh Zn/Br_2 battery (sufficient to provide energy storage for a single-family dwelling with a photovoltaic power source) have been built and tested.

Sophisticated battery testing laboratories have been established and are operating very effectively. The National Battery Testing Laboratory (NBTL), the Battery Energy Storage Testing (BEST) Facility and the Sandia National Laboratory Systems Testing Facility provide comprehensive and unbiased testing of batteries for various energy storage applications. Testing of Pb/PbO_2, Fe/NiOOH, Zn/NiOOH and LiAl/FeS batteries and modules at NBTL has provided extremely valuable feedback to DOE and various battery developers. The BEST Facility has installed an advanced 500-kWh Zn/Cl_2 battery, and cycle-life performance testing of Zn/Br_2, $H_2/NiOOH$ and advanced Pb/PbO_2 batteries at Sandia National Laboratories has identified unanticipated failure modes. This example of strong interaction between DOE, national laboratories and industry has proved to be very beneficial to the energy storage program.

Significant progress has been made in high-performance energy storage and conversion system research:

- New high-temperature LiAl/FeS molten-salt cell components permit more than 800 deep-discharge cycles (which meet a long-standing goal) and freeze-thaw capability.
- Innovative cell designs for the mechanically-rechargeable Al/air battery allow rapid refueling with aluminum anode plates.
- A high-temperature water electrolysis system has been fabricated and characterized, demonstrating higher electrical efficiency than that achieved by low-temperature systems.

Transfer of DOE-sponsored technology to the private sector has been very successful:

- New air-electrode technology has been developed for use in chlorine/caustic cells. A cooperative DOE/industry/university program was completed in 4 years, resulting in a one-volt reduction in cell potential. This breakthrough offers major energy savings in chlorine production, and a one-year lifetime has already been demonstrated in a commercial cell (Eltech Systems Corp.).
- A novel sealed lead-acid battery, capable of 1000 deep cycles, has been developed. Commercialization by Gould, Inc. is in progress.
- The development of solid-polymer electrolyte water electrolysis systems (General Electric) has resulted in private-sector commitments to commercialization strategies which

address small user markets.

- The development of a prototype sulfuric acid/water chemical heat pump (Rocket Research Corp.) has led to successful characterization of these systems. The private sector is now committed to identifying commercial ventures, with initial spinoff applications for sulfuric acid concentrators.

- Construction of an underground compressed air field test facility was accomplished by Battelle Pacific Northwest Laboratory near Pittsfield, Illinois. After initial tests (1983) the facility was transferred to the Electric Power Research Institute (EPRI).

- Construction of a superconducting magnetic energy storage system was accomplished by Los Alamos National Laboratory. It is now being used to damp power oscillations on the Bonneville Power Administration/Western U.S. Power System.

- A fiber-composite material flywheel with a 79-wh/kg capacity was demonstrated. A DOT-sponsored flywheel bus is being supplied with a DOE-sponsored Garrett Flywheel/ Electric Drive System, Volvo Motors is developing a flywheel bus drive system, and NASA is planning use of composite flywheels for space applications.

The overall direction of the energy storage program has been to encourage private-sector commercialization (or utilization by other federal agencies) of near-term technologies with "spin-off" possibilities. There has also been a general movement away from limited-performance systems (e.g. lead-acid batteries, flywheels, etc.) and toward high-performance systems (e.g. sodium/sulfur batteries).

Future Prospects

At this time, there are no clear winners of the (international) race to develop an energy storage technology capable of substantial penetration of commercial markets. Although several technologies are viable candidates, none in its present form can meet the stringent performance, cost, durability, and efficiency requirements. However, it is important to keep in mind the history of energy storage system development. For example, during the 1800s only a single practical battery system emerged -- namely lead-acid. By the early 1900s iron/nickel oxide batteries became available, in the 1960s cadmium/nickel oxide and zinc/silver oxide batteries were developed, and in the 1970s hydrogen/nickel oxide batteries were employed in space applications. These systems have seen increasing application in both aerospace and consumer markets. It is clear that new systems require significant periods of R&D before they are ready for the very competitive market place, but with proper incentives and with federal involvement winners will emerge. Thus, while the probability of success in any one energy storage system may be 50 percent or less, continued research is virtually certain to result in the successful development of one or more of these high-performance systems.

Recent funding levels* for the energy storage program have permitted the sustained development of only a few systems at modest effort levels. As the most promising systems advance to the stage where testing of larger systems becomes appropriate, increased funding levels are necessary to ensure proper evaluation. For example, at least five electrochemical energy storage systems (sodium/sulfur, zinc/bromine, lithium/metal disulfide, zinc/nickel oxide and metal/air) show sufficient promise to merit some level of serious development activity, which requires $1M-$5M per year per system. Recent funding levels** for the electrochemical part of the energy storage program have permitted only the sodium/sulfur and zinc/bromine systems to undergo substantial development efforts. It is strongly recommended that the funding level for the total energy storage program be established at an appropriate level to maintain development (and supporting research) efforts on 5-10 of the most promising candidate energy storage/conversion systems. It is suggested that a $40M/year energy storage budget is appropriate.

Provided that an adequate funding level is maintained, prospects look bright; successful development of one or more advanced energy storage systems can be expected in the 1990s. This can provide a very significant cushion against possible future petroleum shortages, and can play a major role in avoided costs of new power plants.

Need for Federal Funds

Leadership in energy storage technology presently resides in the U.S., Japan, and Western Europe. The central focus of this nation's R&D has been the Energy Department's programs to develop advanced energy storage and conversion systems for electric vehicles and electric utilities. As a result of these programs, the U.S. has an apparent technical lead in several of the candidate systems and a competitive position in others. However, the U.S. does not enjoy a clear-cut superiority, and in recent years we have been an importer of this technology. Continued federal support would allow the U.S. to maintain its momentum to establish a firm competitive edge in energy storage and conversion technology.

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* Approximately $25M/year in FY 1983 and FY 1984.

** Approximately $18M/year in FY 1983 and FY 1984.

It is clear that industry alone will not pursue battery R&D at the required level of effort. Some of the reasons are:

1. There is a cost barrier to the industrial development of advanced storage/conversion systems suitable for electric vehicle or utility load-leveling use. For example, only 1.7 percent of the revenue from sales made by battery developers is returned to their R&D program. Of that, 90 percent is used to improve products for existing markets, and support for R&D work directed at long-term potential is at most 0.17 percent of sales. The reason for lack of industrial spending on this R&D is that there is no well-developed market for either electric vehicle or utility load-leveling systems; therefore the cost and risk are both high.

2. The major markets for advanced storage/conversion devices are the automobile manufacturers and the electric utilities. Both have narrow profit margins which make technology shifts risky. For example, to make current technology batteries profitable to utilities, the designs must be improved to double the system life (from the current 10 to about 20 years), and the costs must be reduced by about 50 percent. This would require large investments over a relatively long period of time (5 to 15 years), requiring resources that neither the utilities nor the battery manufacturers have.

3. There is a technical risk which adds additional weight to the economic risk. This risk involves the development of energy storage systems that require substantial and simultaneous improvement in four competing areas of performance: specific energy, specific power, cycle life, and cost. For example, without extensive development, electric vehicles will continue to suffer from an unfavorable position relative to internal-combustion engine vehicles in terms of initial cost and performance.

4. There are a number of viable candidates for both electric vehicle and stationary energy storage applications. At this time, it is not possible to identify an eventual winner, so individual companies are reluctant to invest their funds.

5. New provisions of the Economic Recovery Tax Act (PL 97-34) offer tremendous advantages to companies who invest in new production capacity. This will cause even more emphasis to be placed on near-term investments in conventional technology and increases the need for government participation in long-term R&D efforts.

6. U.S. companies are not operating in a totally "free" market. Developers in Japan, West Germany, and England are receiving strong financial support from their governments. Without strong federal support, American industry will find itself at a disadvantage with respect to foreign competition. This can only injure further the U.S. balance of trade.

Long-range R&D on advanced systems for energy storage is a highly appropriate use of public funds because of the broad range of positive impacts that could accrue to various national programs (nuclear, fossil, and renewable energy) and national problems (dependence on foreign petroleum, federal deficits, and damage to the environment). The absence of existing markets for the eventual application of advanced storage systems makes long-range R&D a high-risk undertaking, which underscores the crucial need for continued government support.

Recommendation

It is recommended that the Energy Department's Energy Storage Technologies Program continue to receive the support that has made possible the existing strong R&D effort, and which has involved major research institutions, including national laboratories, major universities and industrial laboratories. Specifically, continued Federal support at a level of $40M per year should provide funds adequate for research and development on the most promising candidate systems to the point of technology transfer to industry.

Mrs. LLOYD. Well, thank you very much, Dr. Cairns, for your testimony.

Dr. Boom, we look forward to hearing from you.

Dr. BOOM. Thank you, Madam Chairman. I appreciate the opportunity to present this testimony. My name is Roger Boom. I am Director of the Applied Superconductivity Center, University of Wisconsin, and manager of our 12-year-old superconducting magnetic energy storage project, called "SMES."

In 1979, 1980, and 1983, the Wisconsin group has testified before this committee to request that Wisconsin SMES research and development be funded for $15 million. We are here today to make that same request.

I appreciate this opportunity also to testify with National Laboratory representatives, because of the interactions we have had with DOE and the National Laboratories during the course of developing SMES at Wisconsin.

If competitively priced, SMES has many desirable features and would be overwhelmingly selected over battery storage now supported by DOE.

I represent an industrial university team composed of the University of Wisconsin research engineers and Wisconsin utility engineers from the five investor-owned electric utilities in Wisconsin. Mr. Donald Helfrecht, president of Madison Electric, has testified on this team effort on the preceding industrial panel. Our joint research work over the past 10 years results in an attractive future for SMES.

The Bechtel Corp. evaluates Wisconsin SMES to be comparable in cost to the coal unit it would replace. In the past, Wisconsin has had DOE funds of about $3 million. Now that support is being reinstated at a modest level. However, Federal assistance is needed at the $15 million level of R&D funds for the next 3 or 4 years. This is the R&D phase that Dr. Kalhammer referred to.

The Wisconsin group would allocate the funds about 75 percent to industrial partners, about 25 percent to utility and university staffs to lead the research. Following the successful completion of the R&D phase, which confirms and tests components on an industrial scale, a large SMES pilot plant should be built and tested by 1993.

Federal and State and private utility funds could jointly support that proof-of-principle operating plant. If economically successful, SMES could expand into a multibillion-dollar business a year. We think it is appropriate for the Federal Government to engage in this expensive, long-range, high-payoff initial research. Utility companies are constrained in initial R&D funding but can more easily fund large demonstration plants later.

Based on our long experience with SMES funding, we strongly urge absolutely clear directed funding to the university industrial team at Wisconsin. Either the university or the utilities could be the prime contractor. The importance of funding Wisconsin should be recognized. Wisconsin is the inventor of the Graetz bridge high-efficiency storage concept. Only Wisconsin has persisted over the past 12 years to work on that SMES, so that it is a viable candidate. Only Wisconsin offers the university industrial team that can proceed immediately. Only Wisconsin seems capable of the interest to deliver a successful SMES final product.

Our Wisconsin experience over the past 8 years of on-and-off DOE funding is that DOE does not recognize the potential of our university-industry team. DOE should recognize that large projects in energy storage can be successfully managed by a university in a university-industry environment.

I personally have spent most of my professional life in industry and did manage successful R&D projects of the size. Our utility partners have the largest budgets in the United States and are easily capable of managing a $50-million 4-year effort.

The new construction utility budget in Wisconsin is typically about a half-billion dollars a year. Our other industrial partners are well recognized leaders in their field.

If the United States wants SMES technology transfer from the University of Wisconsin to industry, there is no better way than to support our team effort for this $15 million proposal.

Our basic problem in getting DOE attention for SMES probably stems from the DOE dedication to their own national laboratories and the programs favored by those laboratories.

The summary statement in Document DOE/S-0025, page 17, "An Assessment of the Relationship Between the Department of Energy and Universities and Colleges," August 1983, "A widespread perception exists in the academic community that the department's national laboratories have an unfair institutional advantage in obtaining DOE support in some areas."

We concur with that statement in regard to SMES. Our major DOE directives in the past have been to work with one of the national laboratories, and our small DOE funds are currently managed by a national laboratory.

This national laboratory intrusion into a technology which could be directly transferred to industry by a university in my opinion is counterproductive.

It is my personal opinion that the major energy programs in the United States could be greatly improved if a new university industry department of energy were formed to parallel the existing national laboratory department of energy.

Our Wisconsin SMES program could be greatly improved if funding could be directed to Wisconsin without national laboratory intervention.

Thank you, Madam Chairman.

[The prepared statement of Dr. Boom follows:]

STATEMENT OF R. W. BOOM, PROFESSOR OF NUCLEAR AND METALLURGICAL ENGINEERING

UNIVERSITY OF WISCONSIN
MADISON, WISCONSIN

on

Diurnal Superconductive Energy Storage

before the

HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
Subcommittee on Energy Research and Production

March 7, 1984

In 1979, 1980 and 1983 the Wisconsin SMES group has testified before this committee to request that Wisconsin SMES research and development be funded for $15,000,000. The first year of that funding was listed in the FY-83 Continuing Resolution but did not survive into the final budget. I am here today to again make the same request. I appreciate this opportunity to testify with National Laboratory representatives because of the interactions we have had with DOE and the National Laboratories during the course of developing SMES at Wisconsin.

SMES is the system for the storage of night-time inexpensive electric energy from base load generators to be discharged the next day during high demand periods. The SMES storage system is a large superconducting solenoid which stores energy in its magnetic field. If competitively priced SMES has many desirable features and would be overwhelmingly selected over battery storage or compressed air storage, both now supported by DOE.

I represent an industrial-university team composed of University of Wisconsin research engineers and Wisconsin Utility engineers from the five investor owned electric utilities in Wisconsin. Mr. Donald J. Helfrecht, President of Madison Gas and Electric has testified on this team effort on the preceding industrial panel.

Our joint research work over the past 10 years results in an attractive future for SMES. The Bechtel Corporation evaluates the Wisconsin SMES to be comparable in cost to the coal unit it could replace. Based on that study, EPRI Report RP1199-17, the Wisconsin group is now in the process of getting research support from EPRI. In the past Wisconsin has had DOE funds of about $3,000,000 and now that support is being reinstated at a modest level.

Our purpose in appearing today is to repeat the known facts accepted as unique benefits for SMES and to plea for Federal assistance to complete the SMES research and development. The unique benefits for SMES as Mr. Helfrecht pointed out are,

- 95% storage efficiency
- 95% availability
- 50 year lifetime
- intermediate generator replacement
- rapid power reversal (33 milliseconds)
- spinning reserve
- system stability
- system regulation

Federal assistance is needed to provide $15,000,000 R&D funds in the next 3 to 4 years. The Wisconsin group would allocate the funds about 75% to industrial partners and about 25% to Utility and University Staffs to lead the research effort.

The work to be undertaken in the 3 to 4 year period falls into five categories,

1. conductor development, including successful commercial fabrication and demonstration
2. axial structure design, development and test
3. radial structure design, development and test
4. system engineering designa and test
5. small model storage unit to demonstrate component fabrication and system tests.

Following the successful completion of the R&D phase, which confirms and tests components on an industrial scale, a large SMES pilot plant should be built and tested. Federal, state and private utility funds could jointly support that proof of principle operating plant. If economically successful SMES could expand into a multi-billion dollar per year business.

We think it is appropiate for the Federal government to engage in this expensive long range high payoff initial research. Utility companies are constrained in initial R&D funding but can more easily fund large demonstration plants later.

Based on our long experience with SMES funding we strongly urge absolutely clear directed funding to the University-Utility team at Wisconsin. Either the University or the Utilities could be the prime contractor. The importance of funding Wisconsin should be recognized. Wisconsin is the inventor of the Graetz bridge high efficiency storage concept. Only Wisconsin has persisted over the past 12 years to work on SMES so that it is a viable candidate. Only Wisconsin offers a University-Industrial team than can proceed immediately. Only Wisconsin seems capable of the interest to deliver a successful SMES final product.

Our Wisconsin experience over the past eight years of on and off DOE funding is that DOE does not recognize the potential of our University-Industry team. DOE should recognize that large projects in energy storage can be successfully managed in a university-industry environment. I personally have spent most of my professional life in industry and did manage successful R&D projects of this size. Our Utility partners have the largest budgets in the U.S. and are easily capable of managing a $15,000,000 - 4 year budget. The new construction utility budget in Wisconsin is typically about 1/2 billion dollars per year. Our industrial partners are well recognized leaders in their fields. If the U.S. wants SMES technology transfer from the University of Wisconsin to Industry there is no better way than to support our team effort for the $15,000,000 proposal.

Our basic problem in getting DOE attention for SMES probably stems from the DOE dedication to their own National Laboratories and the programs favored by those laboratories. As stated in document DOE/S-0025, page 17, An Assessment of the Relationships Between the Department of Energy and Universities and Colleges, August 1983: "A widespread perception exists in the academic community that the Department's national laboratories have an unfair institutional advantage in obtaining DOE support in some areas." We concur with that statement in regard to SMES. Our major DOE directives in the past have been to work with a National Laboratory and our small current DOE funds are managed by Los Alamos National Laboratory. This National Laboratory intrusion into a technology which could be directly transferred to industry by a university is counterproductive.

The major energy programs in the U.S. could be greatly improved if a new University-Industry Department of Energy were formed to parallel the existing National Laboratory Department of Energy. Our Wisconsin program in SMES could be greatly improved if funding could be directed to Wisconsin without National Laboratory intervention.

Mrs. Lloyd. Well, thank you, Dr. Boom.

I would like to compliment all three of you on your very fine statements. You certainly addressed the issues of concern.

Mr. Carlsmith, where is industry going in the directions we're working on in ORNL? Where are they putting their R&D dollars? And what are their goals?

Mr. Carlsmith. In the electric energy systems work, the principal industrial support is through the EPRI, the Electric Power Research Institute. We work closely with them on these programs, have frequent communications with EPRI, and in fact participate in many of their committee meetings.

And the general distinction between the DOE work and the EPRI work is that the EPRI work is increasingly directed toward short-term improvements, whereas the DOE work has moved steadily toward longer range, higher risk types of research. So that there's—at the present time I am not aware of any area in which there is a significant amount of overlap between the two programs.

In thermal energy storage, there's very little industrial research going on at the present time. The DOE programs represent essentially all that's being done in developing new systems.

Mrs. Lloyd. Well, do you feel that we could work in a greater effort to coordinate the DOE programs that are—that are done, though, by industry? How could we work better and coordinate our activities better?

Mr. Carlsmith. In my opinion there is good coordination currently. We make a great deal of effort to coordinate our programs with the people in industry who are working in similar areas. I don't think that that's a problem at the present time.

Mrs. Lloyd. You're referring to the work at ORNL in that capacity?

Mr. Carlsmith. Well, I speak principally from my experience at ORNL, of course. But I think in the areas that we're talking about now, the ones that I know about, there is good coordination in every case.

Mrs. Lloyd. Would any of the other members care to comment on this coordination of activities?

Dr. Cairns. I think there in some cases could be improved coordination in the sense of better technology transfer accompanied by cost sharing. In our lead center role at Lawrence Berkeley Laboratory, as one of the criteria for selecting industrial subcontractors, we include an important element of cost sharing. In many cases, as Roger Carlsmith points out, that already exists. I think that that is a good sign, but it could be advanced farther, and we are making efforts to do that in our involvement in the electrochemical R&D area for battery energy storage.

The coordination between the Department of Energy programs and those at Electric Power Research Institute I think is good across all of these areas of technology that we're discussing this afternoon. There are joint meetings. There are joint planning sessions.

Department of Energy representatives are invited to participate in the review of EPRI-funded programs and EPRI representatives participate in the review of Department of Energy funded programs. I think that has been very effective, and Dr. Kalhammer has pointed out that EPRI has done a very good job adjusting the kinds of work that it supports in order to respond to the sometimes rapidly changing policies of the Department of Energy.

Mrs. LLOYD. Would you care to comment on the status of the energy storage technologies in foreign countries?

Dr. CAIRNS. Yes; the international competition, especially in the electrochemical area, is highly intense. For example, in the sodium-sulfur battery area, which is a technology invented in the United States, a number of other countries have challenged our leadership by massive investments of manpower and money.

For example, the Brown Bovari Co. of Germany has a massive effort. There are two massive efforts in Japan. There were two—there are two large efforts in England, and a significant effort in France.

The British and French efforts have had some tie-in with the U.S. efforts, but those have been brought about for the purpose of importing technology from those foreign countries, technology in an area that the United States invented.

So I would say that our leadership position in a number of these electrochemical technologies is being very seriously challenged, and unless we maintain and strengthen our research and development activities, we could be importing Japanese or German technology that is based upon U.S. original research.

Mrs. LLOYD. That's very interesting.

Dr. Boom, what are the major technical problems that we need to address as we bring SMES to full-scale commercialization?

Dr. BOOM. There are about four major problems. One is the conductor. This requires a successful development and commercialization of the composite niobium titanium and aluminum conductor. It needs a new kind of epoxy fiber glass material for low thermal conductivity at high stress levels. That is a second item of materials.

SMES needs a cheaper niobium titanium, which we're working on, and a very considerable tour de force by a major commercial industrial company for field fabrication of a precise liquid helium large dewar vessel.

In contrast to most projects, this project does not need a pilot plant to be built to see if it would work. It obviously will work. The conductor has 100 times more aluminum in it, for example, than usual. So we are really going to build the first pilot plant to find out what it costs and to find out whether it can be built.

So the aims and the goals of our program are more in the nature of preproduction, development, research and engineering than for a scientific discovery. As compared to the magnetic program in fusion, this is very simple. The only problem is that it's enormously large.

Mrs. LLOYD. Are the relative field effects generated by the system something we should be concerned about for current health effects?

Dr. BOOM. That's a very important area, the effects of d.c. magnetic fields on persons. That's not known. It's also not known if there is any danger. But on the other hand, there is no Federal guideline yet so the first environmental impact statement will break new legal grounds in defining what is the allowed field for this device.

The Bechtel Corp. decided a 5 to 10 gauss perimeter should be a fenceline around the device.

We don't have the answers, but d.c. fields aren't thought to be serious health hazard.

Mrs. LLOYD. Would—Mr. Carlsmith or Dr. Cairns, would you care to comment on the practicality of this system?

Mr. CARLSMITH. I am sorry, I didn't hear the question.

Mrs. LLOYD. We're talking about the superconducting magnetic energy storage system as proposed by the University of Wisconsin, Dr. Boom.

Mr. CARLSMITH. Yes.

Mrs. LLOYD. would you care to comment on this system?

Mr. CARLSMITH. No; I really don't have a comment on that.

Mrs. LLOYD. Well, I have one last question for you. I think you know that the mission of this committee is to initiate and promote Federal funding at an appropriate level for technology that can be transferred to industry. And it's not only to fund technologies that we think are promising, but it's to fund technologies that we can see getting to the marketplace, that have the potential for going to areas for economic expansion and for stability as well.

At what point do you think our federally funded programs should be appropriately transferred to industry? I want all three of you to comment on that, if you will, please.

Dr. CAIRNS. I think it's important to judge each field individually based upon the type of industry that is already in place and based upon whether or not there is an established market for the technology in question.

For those technologies where there is already an established market, such as an improved lead-acid battery for automotive applications, the advantages of an improved device of that sort where there is an established market are readily perceived by the existing industry and, therefore, it's not so necessary to carry that technology to an extremely advanced state of development before industry will see the advantage and be willing to invest in adopting that into its product line.

Where there is not already an established market, such as, battery energy storage for utilities or electric vehicle propulsion batteries, it's necessary to carry the technology much farther and reduce therefore the risk of investing in this new business area, because aside from the technological risk there is a very real and very significant marketing risk for any new product line. And as was pointed out earlier, for example, an electric vehicle would most sensibly be produced by existing automotive manufacturers and would compete for a large segment of the same market with the existing product. Therefore, the manufacturers would have to be convinced of some inherent superiority of the new product or some special market niche which has not yet been demonstrated.

So in order to obtain the industrial takeover of these new technologies where no current market exists, it's necessary to carry the technology to a rather advanced state of development such as there remains little technological uncertainty about the success of the product.

Mrs. LLOYD. Would you care to comment?

Mr. CARLSMITH. I think Dr. Cairns expressed it very well. The only thing I would add to his comment is that I think it's a mistake to—to look at technology transfer as something that's done at one time after the research and development is completed. In all of our programs, we try to the extent we can to involve industry in the process right from the beginning of the research and to discuss with them as we go along what the next step should be, what additional Government involvement is needed and at what point the technology can be transferred completely to industry.

We do this through principally subcontracting with cost sharing arrangements right from the start and with increasing cost sharing from the industrial firms as we go along. We do it also through—in virtually all of our programs—having advisory and guidance committees with industrial participants on the committees to discuss with them as we go along this question that you're asking.

Mrs. LLOYD. Thank you.

Dr. Boom, would you like to add your comments?

Dr. BOOM. Yes. On this point I have a few opinions. I have worked in a national lab and industry, and now a university. So I have seen a little bit in all three areas.

I think technology will be transferred automatically when industry wants it. If they don't want it, it's very hard to transfer.

Now, if you're—you're combining your research with a reform of industry or enery saving or something that is socially advantageous but maybe not economically, then you have a problem forcing the transfer.

But by and large, I think, when industry wants it, they take it.

And I believe another important point is how—how do you transfer it? It's not sufficient to deliver a report.

Mrs. LLOYD. I think my objective in asking this question is, how long should we give to the Federal funding on a project before it is a candidate for takeover by the private sector? My point was that how long should the Federal funding go on, Federal funding should go on, until we say, "Hey, now, this is the time for the private sector to take over"?

Dr. BOOM. I think if it's a good program, it should go on as long as is needed. And I think it should also go on at a satisfactory level so the program gets finished. I believe the DOE record is to fund lots of things inadequately so that nothing ever succeeds. I shouldn't say that. A few things succeed.

Mrs. LLOYD. Well, I think this has certainly been an interesting meeting this afternoon. I regret that we do not have more time with it and more members could not be here this afternoon. But I do thank all of you for the time and effort put into your fine presentations. And I am sure that we will have additional questions that we will submit to you in writing to be included in the record of this hearing.

If there are no further comments, then the subcommittee stands adjourned.

[Whereupon, at 3:33 p.m., the subcommittee was adjourned.]

APPENDIX I

ADDITIONAL STATEMENT SUBMITTED FOR THE RECORD

Statement by Bernard S. Lee, President
Institute of Gas Technology
Submitted to the House Committee on Science and Technology
Subcommittee on Energy Research and Production
Hearing Record on FY'85 Authorization for the Department of Energy

March 7, 1984

Mr. Chairman and Members of the Subcommittee:

My name is Bernard S. Lee. I am President of IGT, a not-for-profit energy R&D organization in Chicago.

To meet its long-range energy needs and to preserve its environment, as well as that of its neighbors, America needs clean fuels which can be utilized at high efficiencies. We urgently need a mature energy policy that directs a balanced and sustained program to develop appropriate technologies to meet these needs. However, caught up in today's fast-paced microchip world in which innovations and obsolescence are measured in years rather than decades, we tend to apply the same criteria of quick turnovers to all national needs. That would be a mistake in the energy field. Energy policies must be established with long-term stability and security as top priority, paying special attention to the available and accessible energy sources, both in the U.S. and in specific geographic locations in the world.

From a world perspective, we should focus our attention on the steady growth in population, especially in developing countries. Nations that historically have existed on extremely low per capita energy consumption represent sources of explosive energy demand as they respond to internal pressures for even a modest improvement in living standards. It is pointless to expect those nations that have substantial energy resources and large populations to become significant energy exporters because their rising domestic demands will soon require all their supplies. For nations without substantial energy resources, growing populations will exert enormous pressure on the distribution of available world energy resources.

In the past, we oversold the nuclear option. Mesmerized by the promise of inexhaustible energy supply, we have disproportionately emphasized that option in terms of R&D expenditure in anticipation of unrealistically rapid deployment of nuclear installations. On the other hand, we undersold and neglected fossil fuel and renewable energy resources to the point where our largest indigenous energy resource is grossly under-utilized. The result is an unbalanced energy mix that will not lead to long-term stability.

We must have a maturity of energy policy for the United States which ensures the smooth flow of technology from the laboratory to commercial use and which realistically addresses future energy options. Although we fund large amounts of energy R&D, we fall behind many other countries which have adopted a policy of continuing, consistent and adequate funding of R&D to develop their indigenous energy resources. The International Energy Agency recently published a review of the 1982 national programs of R&D in the IEA countries. It is interesting to note that the United States is 9th in the ratio of 1982 government expenditures on energy R&D to gross domestic product, and 10th in the ratio of energy R&D to total primary energy demand. If nuclear R&D is excluded, the United States falls to 11th and 16th, respectively, of the 19 countries in the review.

I am deeply concerned by the complacency into which we have been lulled by the current energy situation. The issues on the public's mind are defense, toxic waste, entitlements, education, world peace, but not energy. Such misplaced priority is myopic. We know that fossil fuels will have to provide the bulk of our energy needs well into the 21st century, until renewable resources and, possibly, fusion energy can assume major roles. But, if we look at conventional oil and gas, warning signals are already evident. Domestic oil reserves peaked in the 1950's and have been declining ever since. The U.S. Geological Survey has warned that world oil resources may be even smaller than conservative estimates. Let us not forget that we still import large quantities of oil, and most energy analysts project even higher imports in future years. This has obvious implications for national policy on security and economic well-being.

The natural gas situation is similar. Proved reserves peaked in the mid-1960's and have dropped sharply since that time. Since 1967, yearly additions to reserves have been less than production for every year except 1981. Although indigenous natural gas supply is somewhat more favorable than oil supply, eventually we must turn to imports, development of unconventional gas sources, and synthetic gas to supplement natural gas supplies.

In this atmosphere of complacency, less support is also being given to efficient utilization technologies and applications, even though it has been amply demonstrated that conservation is capable of sharply reducing energy requirements and costs to the energy consumer. Renewable energy sources, too, are receiving less attention although these must become part of our future energy supplies.

A mature energy policy must preserve the environment. The acid rain issue is one of national and international concern. The expanded use of coal, our most abundant resource, must be anchored upon a technically sound and efficient base that complies with present and projected environmental regulations. The fundamental way to solve acid rain is first to totally remove sulfur and nitrogen from the coal by gasification and downstream processing and then to burn this clean fuel gas in advanced efficient combustion equipment. The more efficient the fuel utilization step, the less resource will be needed and the less pollutants emitted. Examples of coal gasification plus efficient utilization include cogeneration, combined cycle or fuel-cell power generation, industrial fuel gas, substitute natural gas, and chemical synthesis. Stop-gap measures to provide marginal improvements to alleviate immediate public pressures do not eliminate the root causes of acid rain, and therefore cannot succeed.

The current Federal R&D funding supports long-range, high-risk technologies. That alone is not enough. We need more than just basic research that enriches the scientific literature. Energy research is principally applied research; we must support the whole chain of development, from basic research to commercial applications. Yet, the current Department of Energy program limits technology development support only through the proof-of-concept step; the key process development and commercial demonstration steps are being left to private industry. However, these steps are the most costly and high-risk links in the chain. They require a time span of 10 or more years. In today's economic environment the private sector cannot undertake these risks. Unfortunately, the distinct possibility exists that world energy supplies will be interrupted at much shorter intervals than 10 years, and we as a nation will be caught unprepared. That risk is greater and will cost the nation more than the risk and cost of getting ourselves prepared through the implementation of a mature energy policy.

For FY'85, two specific recommendations for programs within this Subcommittee's jurisdiction are highlighted below.

HYDROGEN

A leading candidate for the fuel of the future is hydrogen derived by splitting water by using high temperature energy from nuclear fission, fusion or solar sources. To accomplish this, it is necessary to continue development of thermochemical or thermoelectrochemical cycles. Three hybrid cycles have been identified on a laboratory scale as having the potential to accomplish efficient and, ultimately, cost-effective water splitting. The three involve copper sulfate-copper oxide, zinc sulfate-zinc oxide, and cadmium chemistry.

IGT supports $3 million to continue the work on hydrogen research and specifically recommends $1 million for systems evaluations, including reaction kinetics, process/energy source interfaces, product purification and engineering optimization of the cycles.

THERMAL AND MECHANICAL ENERGY STORAGE

Thermal Energy Storage

Thermal energy storage benefits both energy efficiency and capital and operating costs. It can recover and store the energy exhausted in many processes for reuse, thus reducing primary fuel requirements, and it can improve the load factor of utilities by reducing added capacity requirements. IGT is developing a family of phase-change composite thermal storage media that allows direct-contact heat transfer. This concept has a wide range of applications from thermal installations to utility load management. Significant cost benefits have been projected for these composite systems compared to conventional sensible heat storage systems. Proof-of-concept testing is now underway for industrial applications. Expanded R&D is needed in the identification of technical and economic goals for potential markets, measurement of physical and chemical properties of potential media materials, optimization of media thermal and physical behaviors within expected operating conditions, media selection/development to fit application temperatures and operating requirements, and study of materials compatibility between media, containment, working fluids, and auxiliary components.

IGT recommends $4 million for the intensified development of thermal energy storage using composite molten-salt phase-change materials.

Thank you for the opportunity to present my views.

APPENDIX II

SUPPLEMENTAL QUESTIONS AND ANSWERS FOR THE RECORD

Department of Energy
Washington, D.C. 20585

March 22, 1984

Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Production
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Madam Chairman:

On February 22, 1984, Assistant Secretary Shelby T. Brewer, accompanied by John R. Longenecker, appeared before your Subcommittee to discuss the budget request for the Department of Energy's Uranium Enrichment Program.

Following that hearing, you submitted written questions for response to supplement the record. Enclosed are the answers to those questions.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Ms. Nancy Jeffery

Question: In last year's report, the Committee asked the DOE to conduct a comprehensive review of the pricing formula for enrichment services including an assessment of the propriety of including imputed interest in the pricing formula. What has DOE done in regard to this Committee direction? (Although the Committee bill H.R. 2587 was not enacted into law, it did pass the House and the direction to prepare this report was included in both House and Senate Appropriations bills.)

Answer: The pricing formula for uranium enrichment services was an integral part of the Department's review which led to the revised enrichment strategy. To assist the Department in this effort, we sought the advice of Arthur Andersen and Company and other management consultants. A copy of their report was forwarded to committee staff. We will continue to review our business practices including our pricing formula in the future to assure that DOE remains a competitive supplier of enrichment services.

Question: Why have the projected revenues for enriched material fallen so dramatically since December 1982?

Answer: Since the mid-1970's the United States position in the enrichment market has evolved from almost a monopoly situation to one of intense competition. Projected revenues have fallen primarily due to a reduction in projected SWU sales. Delays in nuclear power plants coming on line and competition from other enrichment sources have been major factors in these reductions. In addition, worldwide excess inventories have led to the creation of a large, very low priced secondary market for enriched uranium. The Department has received many partial terminations from customers during the past 2 years as these customers have purchased their needs from the secondary market for economic reasons. Thus, the most dramatic change since December 1982 is the partial termination of deliveries by a majority of our Requirements contract holders who are taking advantage of low secondary market prices.

Question: What percent of DOE production will be provided for defense needs?

Answer: Approximately 20 percent of DOE production will be for defense needs in FY 1985.

Question: Does DOE hope to acquire any new contracts to supply enrichment services, and if so, what are the possibilities?

Answer: At this time it appears that there will be few new enrichment contracts executed in the next 5 years covering reactors for which enrichment services have not already been contracted. However, several existing DOE contracts for reactors in Europe will be expiring during the next 5 years for which renewal opportunities will exist. DOE is planning its activities to retain a competitive position from which to attract any new sales opportunities.

Question: Are the prices from DOE's competitors below that of the Department's marginal cost of production? If yes, why doesn't it make sense for the Department to be conservative, close down an enrichment plant, or half an enrichment plant, and if demand exceeds capacity before GCEP is on-line, then purchase the excess on the market?

Answer: DOE's marginal cost of production is significantly below the prices being offered by our competitors. Decisions regarding the potential closing of a diffusion plant will be driven by reactions from the marketplace through acceptance of the new contract. With regard to secondary market purchases, we project that by the late 1980's the secondary market will have been exhausted. Furthermore, it is DOE's position that the secondary market should be cleared by normal market forces rather than by Government intervention.

Question: Please evaluate the option of closing portions of the Portsmouth and Paducah gaseous diffusion plants, including the potential for shifting power requirements to TVA from other suppliers who may be willing to grant relief from their demand charges.

Answer: As stated in the previous question, decisions regarding the potential closing of a diffusion plant will be driven by reactions from the marketplace through acceptance of the new contract. We are currently seeking ways to reduce our power cost from all three suppliers including TVA.

Question: Last year the Department said it was operating at the lowest capacity it could without damaging the process equipment (3,190 megawatts). This year the Department plans to operate at 400 megawatts below FY 1984's level (2,790 megawatts). Has the basis for the Department's position of last year changed? What is the probability of damaging the process equipment at the proposed level?

Answer: The 3,190 megawatt operating floor was established about 21 months ago based on data available at that time. The basis for the Department's current plan to operate the gaseous diffusion plants (GDP) at lower than 3,190 megawatts is that we now have additional operating experience at low power operation and have made some equipment modifications to the GDP's. These include changes in plant instrumentation, use of block valve throttling without valve damage, UF6 freezeout prevention techniques, refined operating procedures, and added familiarity of the plant operators with low power operations. In addition, a new technique for adjusting the pitch of compressor blades in place, which was in the development stage when the 3,190 megawatt floor was set, has been demonstrated in the plant to be highly effective in controlling cell pressures, thus allaying a concern. The variable pitch blade arrangement is relatively inexpensive, and because it restores the efficiencies lost to block valve throttling, which it essentially replaces, the costs involved are quickly recovered.

The additional low power operating experience has also provided added confidence that the standby procedures for preventing deterioration of the barrier in standby stages are truly preserving the barrier quality. Thus, we believe that the three GDP's can be operated safely and reliably at the 2,790 megawatt power level.

Question:	Why is DOE proposing to spend any money on GCEP if it is possible that it will be terminated in FY 1985? Could the buildings be used for an AVLIS plant?
Answer:	DOE is currently conducting a technical evaluation and selection process on the AGC and AVLIS technologies. The results of this evaluation will be available to support a selection between the two technologies in May 1985. During the period of this evaluation, DOE believes that it is most prudent to continue all GCEP project activities at a reduced pace. The principle rationale for this conclusion is that the cost of terminating and restarting GCEP in FY 1985 would exceed the costs of continuing the project at a reduced pace until the technology selection process has been completed. At this time, no evaluation has been performed of alternative uses for the facilities at Portsmouth.

Question: How many Set III machines will be purchased during FY 1985? How did DOE arrive at 25 machines per manufacturer as an optimum purchase level for the machines? If Set III technology is non-viable because it is much too expensive in a two or four-building GCEP, why shouldn't we stop purchasing Set III's entirely and and transfer funding to the development of Set V's?

Answer: In FY 1985, approximately $120 million has been allocated to the centrifuge manufacturers for production of Set III machines. At this funding level, it is estimated that the three centrifuge manufacturers will produce 1,000-1,200 centrifuges in FY 1985. The machine production rate of 25 centrifuges per month was a preliminary estimate of the FY 1985 production rate that has been superceded by detailed planning by the centrifuge manufacturers.

DOE plans to produce Set III machines during FY 1985 due to the following:

1. The cost of terminating Set III procurement and reinitiating it in FY 1985 exceeds by approximately $140 million the cost of continuing to produce Set III centrifuges at this reduced rate.
2. Continuation of Set III production provides valuable learning curve data that should decrease the risks and lower the costs of Set V production.
3. Termination of Set III production would require outlays of about $110 million in FY 1985 to produce no centrifuge machines versus outlays of $120 million to produce over 1,000 machines.

The Set V development program is adequately funded at $72 million in FY 1985 and needs no supplementation to provide sufficient data for a May 1985 decision. Furthermore, if Set III production were terminated, most of the funding designated for Set III production would be required for termination.

Question: Please identify the dollars per SWU cost of a two and four-building GCEP using the current procurement schedule for Set III's and Set V's.

Answer: The requested data are as follows:

Separative Work Unit Costs
$/SWU

	2 Buildings	4 Buildings
Full Cost	$100	$ 62
Forward Cost	57	40

It should be noted that these estimates are based on previously made GCEP construction cost estimates. During the technology selection process, DOE plans to evaluate and rescope all portions of the GCEP project to assure that the design and overall plant economics are optimized. Results of this evaluation will likely modify the estimates shown above.

Question: Why does DOE believe that it can make a reasonable judgment between centrifuge and laser technology in FY 1985 when it is so early in the technology development phase?

Answer: The U.S. Government has been supporting research and development on the AVLIS technology for over a decade and on centrifuge technology for more than 2 decades. The technology evaluation and selection process will be based on a detailed economic assessment of both technologies and an assessment of the technological feasibility based on experimental results from both AVLIS and AGC. By May 1985, full size Set V centrifuges will have been spun for a period of several months to generate performance data and a roughly half scale AVLIS production demonstration facility will have been operated. Additionally, there will be over 1 year's experience with the liquid separator Materials Handling Demonstration Module at Oak Ridge and several years experience on lasers and other key components. Therefore, DOE believes that it will have a substantial economic and technical data base on which to make a decision in May 1985 regarding which of the two technologies should be the primary option for potential deployment.

Question: Wouldn't the immense investment in GCEP mean that AGC would have an advantage over AVLIS because the forward cost for centrifuge would be less?

Answer: During the technology evaluation and selection process, the relative economics of AGC and AVLIS will be considered. Current estimates indicate that the forward costs of both technologies are in the same range, with AVLIS advocates projecting lower forward costs than AGC advocates. These preliminary estimates will be thoroughly evaluated during the technology selection process.

Question: What is the status of Set V machine development and demonstration?

-- How many machines are operating and at what percent of their operating or production goal?

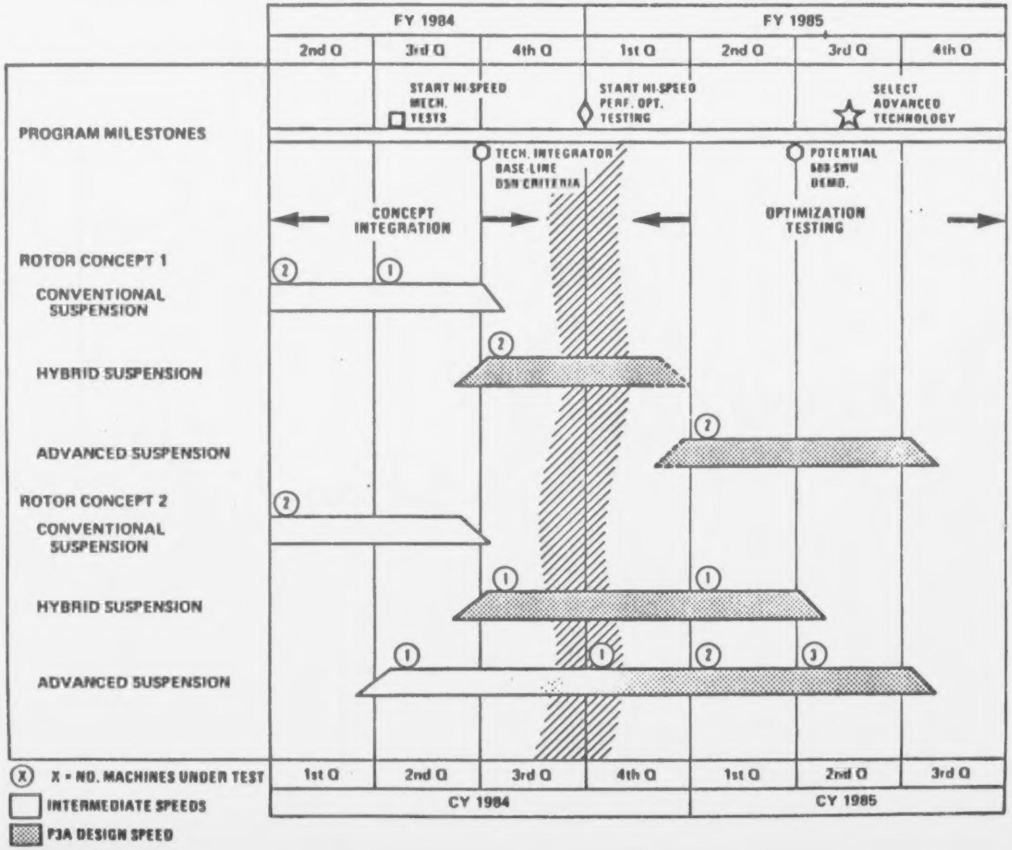
Answer: The complete status of full-scale Set V gas centrifuge testing is illustrated on the attached milestones chart, entitled "Gas Testing of Candidate P3a Configurations." (P3a is the designation for the first generation Set V gas centrifuge designs.)

To date, approximately 15 Set V rotors have been fabricated and 2 centrifuges have been spun at intermediate speed. The test program between the second quarter of FY 1984 and the beginning of FY 1985 is devoted to high-speed mechanical testing of full-scale Set V rotor concepts, utilizing either conventional, hybrid or advanced suspension technologies. These tests are intended to establish the operational features of the rotors at speeds up to and including the anticipated design speed. They will define operating stability boundaries and characterize the rotors in the absence of uranium hexafluoride process gas.

High-speed performance optimization testing will begin about the first quarter of FY 1985 and will include assessment of Set V rotors containing uranium hexafluoride. The rotor and suspension combinations to be tested and the number of such machines under test at any given time are illustrated on the milestone chart. By May of 1985, we expect to have spun 13 rotors at high speed, with approximately 10 of these also being tested while containing uranium hexafluoride.

DWG. NO. K/G-84-983

GAS TESTING OF CANDIDATE P3a CONFIGURATIONS



Question: What is the status of AVLIS development?
- How many grams of uranium and plutonium have been separated into their isotopes?

Answer: The amount of uranium and plutonium that has been separated using the AVLIS process is classified. These data can be provided to you on a classified basis should you so desire.

Question - For how many hours have the AVLIS lasers been operated?

Answer: The AVLIS lasers have accumulated many thousands of hours of operation. Single high power lasers have been operated individually in excess of 1000 hours. The SPP II/VENUS laser system now operates routinely and reliably 24 hours a day, five days a week.

Question: - When will an integrated demonstration of the AVLIS process take place?

Answer: A series of integrated AVLIS demonstrations began in January 1982. These demonstrations utilized laboratory scale subsystems which are prototypic for an AVLIS plant. A near full scale Materials Handling Demonstration Module (MHDM) became operational in February 1984 and is providing engineering data for large scale uranium materials handling. A 1/2 plant scale separator will become operational in 1984 and will perform an integrated demonstration of the AVLIS process at this size by the end of March 1985.

Question: How much is proposed in the budget for construction of the Advanced Centrifuge Test Facility? Why couldn't this facility be cancelled and the AGC machines tested in the GCEP plant or in the Set III test facility?

Answer: In FY 1985, no funds are proposed for the construction of the Advanced Centrifuge Test Facility (ACTF). During FY 1985, the ACTF will be directed to facility design only with the start of construction deferred until after the May 1985 technology selection.

Question: What kind of reception has the new enrichment contract had from DOE's customers? How many customers have signed over to the new contract and how many have announced an intention to do so?

Answer: The reception by the utility industry to the new uranium enrichment contract has been very encouraging. Since the contract was released on January 18, 1984, one customer, i.e., Duke Power, has executed the new contract and as of March 12, 1984, another 14 customers have formally submitted letters of intent to convert to the new contract.

Question: Please justify the potential $10.1 million expense for the lease of a Class VI computer system as identified on page 14 of the Addendum to Volume 4 of the FY 1985 Budget Request for Uranium Enrichment.

Answer: See attachment

Justification for Uranium Enrichment Class VI Computer System .

The U.S. uranium enrichment effort is a $2 billion a year enterprise and is presently under severe competitive pressures. Survival during the near-term and the establishment of a long-term leadership position in this important national business both require intense cost reduction and efficiency improvement efforts combined with aggressive development and deployment and advanced, low-cost enrichment technologies, i.e., the Advanced Gas Centrifuge (AGC) and/or Atomic Vapor Laser Isotope Separation (AVLIS).

Most of the country's uranium enrichment expenditures are either applied directly to or significantly influenced by the Oak Ridge activities. The national effort on the AGC is centered at the Oak Ridge Complex. Important technology development and demonstration, plant design, and production planning efforts for AVLIS are also conducted at Oak Ridge. The AGC and AVLIS programs have been redirected and the major milestones have recently been accelerated in order to advance the deployment and market impact of these technologies. Currently, a mid-1985 decision will be made on selecting between the AGC and AVLIS programs. The selected program will be accelerated and the other program will be funded as a backup technology.

The availability of adequate computing support is a critical requirement if we are to accomplish the goals of these and other programs conducted at the Oak Ridge site. Both the AGC and AVLIS programs depend on large complex analysis and design codes and require sophisticated systems for experimental data acquisition, for control, and for analysis. Advances in this area now permit the use of numerical analyses and computer models that were impractical to use before because of their extensive computer memory and processing time requirements. Improved basic technologies and computer architectures which allow complex algorithms to take advantage of vector processing techniques underly these advances. Much of the development work for the AGC and AVLIS will depend upon the development or refinement and use of numerical analyses and computer models which can take advantage of both vectorization and the processing speed of Class VI computer. Therefore, if we are to be successful in meeting our objectives within the framework of the recently compressed project completion schedules, the Class VI computing capability may be needed beginning in late 1984 or early 1985.

It was determined from a preliminary survey of the Department's existing or planned classified Class VI capability that the enrichment programs Class VI needs could not be accommodated.

DOE has not made a final determination that lease or purchase of a Class VI computer is required at the Oak Ridge complex. However, we felt it was important to identify to the Congress at the earliest possible time the possible need for such equipment. If it is determined that a Class VI system is required at Oak Ridge in FY 1984, the Department will follow the normal procedures of informing the cognizant committees by letter.

Further, if the Class VI system is required to support the enrichment programs, it would also be made available to support non-Uranium Enrichment research programs conducted at the Oak Ridge complex on a time available and cost reimbursable basis.

Question: There are only a few possible outcomes of the selection decision to be made in May 1985. Does DOE have plans for implementation of the decisions it might make? Please describe those plans.

Answer: Both AVLIS and AGC technologies are developing plans to proceed through full scale demonstration and conceptual design if that technology is selected in May 1985. Similarly, both programs are developing plans for phase down if they lose. Plans for technology deployment must await definition of DOE's long-term market share and confirmation of the economics of the selected process.

Question: If the decision is made in May 1985 to emphasize AVLIS, what does DOE plan to do with the Portsmouth centrifuge buildings?

Answer: At this time, no plans have been developed for GCEP in the event that AVLIS is selected.

Question: What program does DOE have to assure that we are abreast of other advanced technologies?

Answer: The DOE maintains, within the contractor organizations, a cadre of experts who evaluate emerging technological developments that would potentially have an impact on uranium enrichment. Both domestic and foreign technological developments are evaluated, and routine reporting is made of these studies.

Question: Assuming success of either one or both of the advanced technologies (AGC and AVLIS), what are DOE's plans for phasing out gaseous diffusion plant capacity and building new capacity using one or both of the advanced methods?

Answer: All decisions on production capacity, the deployment of advanced capacity and/or close down of diffusion capacity will be based on market conditions as defined by acceptance to the new contract.

Question: With the enrichment market DOE envisions, how does DOE plan to finance advanced centrifuges for Portsmouth out of current revenues and simultaneously reduce price and implement the AGC on a schedule adequate to impact cost (and price)?

Answer: A key element of our enrichment strategy is to pace all uranium enrichment program activities to the market share that DOE captures as a result of conversions to the Utility Services contract. The funding available for new capacity additions, advanced technology development, or lower prices to customers varies depending on the percent of our existing customers that convert to the Utility Services contract and the fraction of their total needs that they elect to purchase from DOE. To further increase our flexibility in this regard, DOE is also evaluating options for obtaining funds for new capacity additions from non-federal outlay sources.

Question: Has DOE developed plans for obtaining private investment in the deployment of an advanced technology? If so, please describe them; if not, please tell us whether (and when) such plans will be developed.

Answer: It is the Department's basic objective in all activities to encourage private sector involvement in uranium enrichment. Although full privatization in the near term is probably not feasible, the Department is evaluating means for encouraging private industry's participation. During the next year, the Department will assess the degree of interest in the private sector in privatization activities. The efforts are being timed such that recommendations in this area will be available in concert with the submission of the FY 1986 budget to Congress.

Question: If an advanced technology is to be deployed commercially, how far must the government carry the technology in order to attract private capital? Under what circumstances might private funds be obtained for research and development?

Answer: The Department has begun an activity to determine what will be necessary to induce private involvement in the enterprise, including funds for research and development. This activity will examine the degree of research and development that must be completed to enhance the possibility of obtaining private funds. The Department's efforts are being timed to coincide with the submission of the FY 1986 budget to Congress.

Question: Following the May 1985 decision, if AVLIS is selected, what are DOE's plans for transfer of the technology to industry?

Answer: DOE and the AVLIS contractors are currently evaluating options for involving the private sector in the further development, demonstration, and deployment of the AVLIS technology. A recommendation for this transfer will be selected in FY 1985 as one of the logical steps following technology selection.

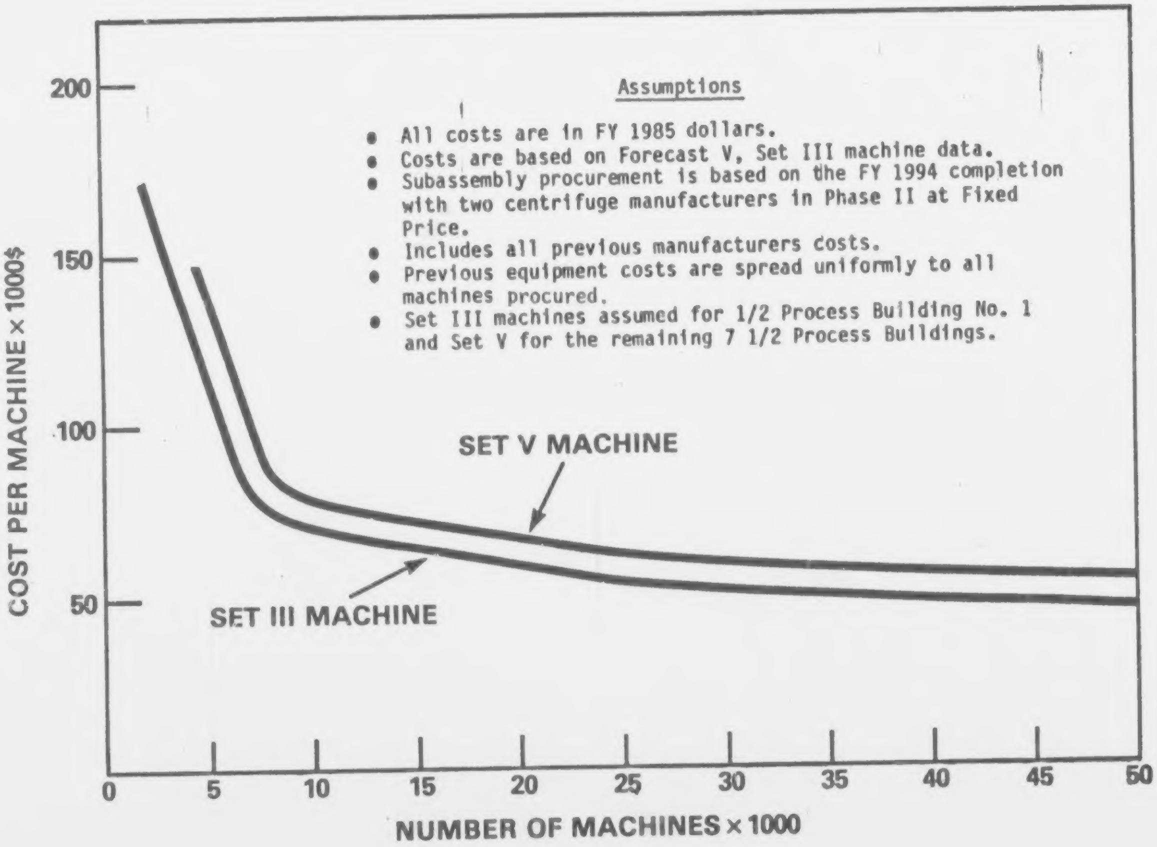
Question: In the case of all gaseous diffusion capacity being eventually replaced, what are DOE's recommendations for producing highly enriched uranium?

Answer: The Department has not yet formulated any plans on how highly enriched uranium might be produced in the eventuality that all other gaseous diffusion capacity is phased out. Possible options include continued use of the existing upper portion or "top" of the Portsmouth gaseous diffusion plant or use of the more advanced technologies for this purpose.

Question: Please provide a graph showing the expected costs per Set V and per Set III machines plotted against the number of machines purchased.

Answer: See attachment

CENTRIFUGE MACHINE UNIT COST



Assumptions

- All costs are in FY 1985 dollars.
- Costs are based on Forecast V, Set III machine data.
- Subassembly procurement is based on the FY 1994 completion with two centrifuge manufacturers in Phase II at Fixed Price.
- Includes all previous manufacturers costs.
- Previous equipment costs are spread uniformly to all machines procured.
- Set III machines assumed for 1/2 Process Building No. 1 and Set V for the remaining 7 1/2 Process Buildings.

Question: Please identify the number of machines to be installed in each building of GCEP.

Answer: Each process building has positions for 5,760 centrifuge machines. The number is the same if they are Set III or Advanced Gas Centrifuges.

Question: If the best cost scenario for centrifuge is assumed, then 8 buildings of GCEP would be built and all machines would be Set V technology. In this case, what would be the total capital cost of GCEP?

Answer: At this time, the number of buildings that may be constructed at the GCEP site under review will be determined by the technology decision in FY 1985 and response to the new contract. From previous evaluations, we estimate the cost of a GCEP plant consisting of eight buildings of Set V machines completed on a 1994 schedule would be about $8.5 billion in 1985 dollars. We are now rescoping the GCEP project and will generate cost of design information for an optimized four building GCEP. This information will be available in late 1984.

Question: Assuming that the total capital cost is still $9 billion, the total production capacity is 27 million SWU/year, that the imputed interest is 10%, and that the facility is amortized over 25 years, then the total cost per year is $900 million in interest plus $360 million in capital, or $1260 million/year. If this is divided by the capacity, a capital cost of $47/SWU results. If this is added to the projected operating costs of $20-$30/SWU, a total cost for GCEP production of $67-77/SWU results.

a. Please provide the same type of analysis for a two and a four building GCEP, and include the costs of the initial Set III procurements.

b. Please evaluate and compare the results above with the total unit cost of GDP production. Also, please evaluate and compare them with the total unit cost of GDP production less demand charge payments.

Answer: We would not do this evaluation in exactly the manner described. We would only accumulate interest on the undepreciated portion of the facility. Also, the projected operating costs of $20-30/SWU appear to be much too high.

DOE's estimated unit cost for an eight building GCEP with Set V machines is $44 per SWU. This is based on a total capital cost of $8.53 billion, straight-line depreciation over 25 years, and a 9 percent interest rate.

a. The corresponding unit costs for a two and four building GCEP are $100 and $62 per SWU, respectively.

b. The comparable total unit cost for GDP production is about $107 per SWU with demand charges or about $87 per SWU without demand charge payments.

Question: Government revenues appear to be at a unit price of $94 per SWU. Why do commercial sales command a 50 percent premium? You seem to be losing at least $100 million for government business. Why?

Answer: DOE provides a portion of its production to meet Government requirements for enrichment services. The price charged to Government users is based on the same calculation as to commercial users. However, the price charged to Government users does not include depreciation of plant and equipment or imputed interest.

Question: What amount of response to your new contract will motivate plans to build GCEP beyond two process buildings?

Answer: There is no discrete contract conversion rate that would dictate proceeding with GCEP beyond buildings 1 and 2. Rather, decisions on building more than two process buildings of GCEP are contingent on a strong customer demand and on the demonstrated ability of advanced centrifuge technology to provide an increment of capacity that will result in competitive prices.

Question: What amount of FY 1985 commercial sales will come from production? Inventory?

Answer: Production in FY 1985 is estimated at 10.6 million SWU. Commercial sales are estimated at 10.1 million SWU with Government sales estimated at 2.6 million SWU. Total FY 1985 deliveries will be met from production and 2.1 million SWU from inventory.

Question: How can a meaningful comparison be made in FY 1985 between the Advanced Gas Centrifuge and the AVLIS processes?

Answer: The comparison conducted by DOE will draw on the extensive results obtained from Government supported development of AGC (over 20 years experience) and AVLIS (over 10 years experience). The AGC and AVLIS technologies have common figures of merit when viewed within the boundaries of the uranium enrichment enterprise. Variables such as implementation schedules and costs, cost competitiveness and technical risk are key areas for evaluating the potential and risks of a technology. When considering the relative merits of AVLIS and AGC, a necessary condition is to place both technologies within a common framework. During the coming year, the DOE will (1) conduct a detailed assessment of the relative uncertainties in cost, schedule, and performance for AGC and AVLIS within a common framework, and (2) identify and evaluate business and market factors that would impact AGC or AVLIS technology development and deployment. A mid-FY 1985 decision on the advanced technologies must consider the magnitude of the outlays required and the resultant impact on our enrichment price; the projected needs for enrichment capacity and new technology introduction, and the overall economic and technical potential of each technology. We believe that by mid FY 1985 we will have developed both technologies to a point where an informed decision can be made.

Question: At that time how much production will have been demonstrated by each process?

Answer: In early CY 1985, the AGC program plans to demonstrate the potential of separative performance consistent with the goals for an advanced centrifuge. AVLIS plans to demonstrate a significant fraction of plant production rates (greater than 1,000 SWU/year) in a single segment within the separation system in the same time frame.

Question: At what production rate?

Answer: The AVLIS demonstration will have a capacity greater than 1,000 SWU/year. The AGC goal is to demonstrate a performance of 600 SWU/year per machine. However, the actual production of enriched materials is only one element in an assessment of the overall attractiveness of an advanced technology. Our technology review must consider the technical risks, development costs, production costs, and schedules of each technology. AGC and AVLIS economic and schedule projections that define their baseline programs will be thoroughly evaluated.

Question: On what basis do you forecast SWU sales at higher levels in 1991 than in 1985?

Answer: DOE forecasts SWU sales in 1991 to be higher than in 1985. On-line nuclear generating capacity will be significantly larger in 1991 than in 1985 providing a larger base for enrichment services demand. There are currently, large existing inventories of enriched uranium which are being used by customers to meet a portion of their 1985 needs. This results in 1985 sales being lower than customer use. However, we expect that by 1991 the Utilities Services contract will have eliminated these inventories and that enrichment services contract deliveries will be in balance with actual needs.

Question: Why did you forecast higher sales in 2000, fourteen months ago than you did two months ago? There appears to be a drop from 25 million to 20 million SWU's. Please comment.

Answer: Since the earlier forecast, numerous cancellations or deferrals of additional nuclear projects have occurred. Many of these recent projects were well under construction at the time of cancellation or deferral. Also, the current forecast reflects contract terminations by some non-U.S. customers that had not been projected in the earlier forecast. Additionally, the current forecast anticipates that customers will make use of the Variable Tails Assay Option feature of the new Utilities Services contract in a manner that will result in lower enrichment service sales.

Question: What features about the uranium enrichment program do you believe will motivate private industry to enter that business? What inducement must DOE make and at what cost to the government?

Answer: The Department has begun an activity to evaluate the potential for inducing private involvement in uranium enrichment. Some obvious requirements are that we maintain a stable sales base and operate the enterprise in a cost efficient manner. The Department's evaluation will be timed to coincide with recommendations being available in concert with submission of the FY 1986 budget to Congress.

Department of Energy
Washington, D.C. 20585

June 22, 1984

Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
  and Production
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Madam Chairman:

On February 22, 1984, Assistant Secretary Shelby T. Brewer testified before the Subcommittee on Energy Research and Production concerning the authorization for uranium enrichment.

Following that hearing, with your letter dated May 30, you submitted additional questions for our response. Enclosed are the answers to those questions.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Ms. Nancy Jeffery

Question: Please evaluate the pros and cons of closing portions of the Portsmouth and Paducah Gaseous Diffusion Plants, assuming a low enrichment services demand. Also, please address the potential for shifting power requirements to TVA from other power suppliers who may be willing to grant relief from their demand charges. Please note that we have reformulated this question from the version forwarded to you earlier in order to clarify our intent.

Answer: Assuming that near-term demand is very low, it would be possible to shut down one of the gaseous diffusion plants. The decision of which one would depend on, among other things, economic and reliability considerations for the enrichment enterprise. Both Paducah and Portsmouth have the advantage of low cost electric power from EEI and OVEC. It is possible to shut down one half of the Paducah plant due to its configuration and it would also be possible to shut down the low enrichment portion of the Portsmouth plant. The advantages of these actions would be a reduction in GDP operating costs through personnel reductions at the affected site. The disadvantage would be higher power costs since the power costs at these plants are lower than TVA power costs.

As for the potential for shifting to more TVA power, it would not be economic for DOE to reduce OVEC and EEI power purchases in order to purchase additional TVA power, unless that additional TVA power was priced at rates equal to EEI or OVEC rates. Based on the current estimates for FY 1984, the total (energy + demand) unit costs for OVEC and EEI are 18.0 and 22.5 mills per kilowatt-hour, respectively. The TVA energy unit cost is 24.8 mills per kilowatt-hour and the total power cost (energy + demand) is 34.5 mills per kilowatt hour. Because the current total unit costs for OVEC and EEI are about 50 percent and 35 percent less, respectively, than the TVA total unit costs, it is more economic to purchase the OVEC and EEI power.

Question: Mr. Grant said that Boeing would have "a complete, production-ready Set V design in early 1986." Similarly, Mr. McWhorter stated that by 1987, "several prototype AGC machines would have been tested for approximately one year...." However, your reply on page 11 states that "by May 1985 full size Set V centrifuges will have been spun for a period of several months...." Please clarify the consistency of these separate statements.

Answer: The various comments made about Set V gas centrifuge testing and availability are consistent. Any confusion apparently arises over the distinction between a centrifuge's physical size and its separative work capacity. In the near term, the advanced gas centrifuge development program emphasizes testing that verifies the suitability of specific gas centrifuge components. These include the rotor, end caps, suspensions, gas collection scoops, and other associated hardware. Testing through mid-FY 1985 will encompass full-size Set V centrifuges, but will not necessarily include all end-item components in one specific assembly. We are testing two basic rotor concepts, each with different types of suspension systems, to establish which combination is optimum. The testing proceeds from intermediate to high speed rotation of full (physical) size centrifuges, without and then with the addition of uranium hexafluoride process gas. By mid-FY 1985 we intend to establish the potential for demonstrating separative capacity of 600 SWU per machine-year. Also, by March 1985 we will select the Set V integrated design, based upon the cumulative knowledge gained from the preceeding tests of centrifuge features. The Preliminary Design Review will be conducted in May 1985.

In the event the AGC option is selected over AVLIS, we will continue with centrifuge testing at full size and separative work capacity in FY 1985 and FY 1986. We will proceed in parallel on two paths.

One is to test production model centrifuges as rapidly as possible, to permit introduction into GCEP on an accelerated schedule. The other is to continue testing of full size centrifuges in order to verify their reliability for long-term operation in GCEP. The remarks by Messrs. Grant and McWhorter were based on previous plans that contemplated a more extended schedule for introduction into GCEP. It is our intent to deploy Set V gas centrifuges in GCEP on the shortest schedule consistent with adequate performance and reliability testing.

Question: Dr. Hartig replied during the Subcommittee hearing that a 2-building GCEP with Set III machines had a forward cost of $85-$87/SWU. How is this consistent with your $57/SWU estimate on page 11 of your responses?

Answer: Previously presented estimates on cost of separative work have been based on the existing schedule for deployment of Set V gas centrifuges in GCEP. This is being rescoped and the costs based on Set V deployment in two or four GCEP buildings will be developed during the ongoing technology selection. We do not have the details of Dr. Hartig's calculations, but our estimate of $57/SWU was based on forward costs for a two building deployment of Set V centrifuges. These include capital cost of the facility, the capital depreciated over 25 years, interest on capital at 9 percent, and appropriate operating costs. Dr. Hartig's calculations appear to be based on full cost excluding interest on capital.

Question: Dr. Emmett said that in 1985 "the lasers would be at 20 percent of production scale, and the separator would be a single cell, not a complete multicell array. And we would operate that for like 10 hours which is like one-twentieth to one-fortieth of a full cycle production run. And we would run the multicell collectors like 100 hours, which is a quarter of a production run." This appears to contradict your reply on page 11 that "a roughly half-scale AVLIS production demonstration facility will have been operated." Please clarify.

Answer: There is no contradiction. The largest single piece of equipment, which is to be replicated in an AVLIS plant, is the separator system. The separator to be operated by March of 1985, and referred to on page 11 of our reply, is roughly half the size of an AVLIS production separator pod. The running times of approximately 10 hours are indeed "like one-twentieth to one-fortieth of a full cycle production run" but the physical size of the separator pod is one-half the scale size of a production unit. The separator used in the 1985 enrichment demonstrations will be a multi-cell array operating at plant-like conditions, thereby providing valuable thermal, structural, and operating engineering data, but only one cell will be illuminated initially by the lasers to produce enriched uranium. A separate near full production scale multi-cell array will be operated for at least 100 hours without lasers to provide materials flow engineering data.

The AVLIS production scale laser system will be built by replicating a basic unit called the master oscillator-power amplifier (MOPA) chain. Several of these chains will be contained in the laser system referred to by Dr. Emmett and will produce a total power at 20 percent of production scale. We would need to build five times more chains, but not increase the physical size of the individual lasers or the MOPA chains to achieve production performance.

In summary, the tests planned by the AVLIS proponents, will provide representative data to support a decision between the technologies in May 1985.

Question: Dr. Emmett doubted that in 1985 there would be "an adequate level of demonstration of the technology and its cost factors, given the tremendous commitments that already exist to other technologies." This appears at variance with your expectation (page 11 of your responses) that enough information will exist to make a decision. Is there fundamental disagreement between your two positions in this case?

Answer: The proponents of the AVLIS technology have stated that the process has been proven technically and that an adequate basis exists to determine the costs and performance of the technology. Thus, they support DOE's decision to make the technology selection in mid-FY 1985. Dr. Emmett, in testimony before the Subcommittee on Energy Conservation and Power of the Committee on Energy and Commerce on March 1, 1984, stated his support for the 1985 decision. In addition, a letter from the Director of the Lawrence Livermore National Laboratory indicating his concurrence in the process selection was sent to the Honorable Tom Bevill, Chairman, Subcommittee on Energy and Water Development, House Committee on Appropriations. I would like to insert a copy of this letter into the record.

March 20, 1984

The Honorable Tom Bevill
Chairman, Subcommittee on Energy and Water Development
House Committee on Appropriations
2305 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Bevill:

We have been asked by your staff whether or not we support accelerating the Advanced Gas Centrifuge (AGC)/Atomic Vapor Laser Isotope Separation (AVLIS) process selection from 1987 to 1985. John Emmett has already provided testimony before the House Committee on Science and Technology and the House Committee on Energy and Commerce indicating that, under the difficult set of constraints that face DOE's uranium enrichment enterprise, we fully support acceleration of the process selection.

Early in 1984 we were contacted by DOE/UE indicating that the decision had been made to operate the uranium enrichment enterprise with zero net appropriation, and that the much reduced revenue stream could not support carrying the GCEP project at Portsmouth, the AGC program, and the AVLIS program. It was judged impractical to put a hold on the outlays for GCEP until 1987 when both the AGC and AVLIS processes could be fully demonstrated. Thus the decision was made to accelerate the process selection to 1985 so that one of the two advanced processes could be chosen, thus reducing total annual outlays. Under these constraints for conducting the uranium enrichment enterprise, I am in support of accelerating the process selection to 1985.

Process selection in mid-FY85 will be difficult because AVLIS will not have demonstrated economics at full scale by operating a full plant pod fully illuminated by lasers. Similarly, the AGC program will not have operated a complete, production-qualified, full-scale, set V machine at full speed. Both of these demonstrations were/are scheduled for 1987 and cannot be substantially accelerated. Thus an increased burden is placed on the technical and economic review leading to process selection under this accelerated schedule. In my mind it is imperative that a full-scale peer review be conducted where the AGC community critiques the AVLIS work and assumptions, and the AVLIS community critiques the AGC effort. These critiques should be conducted before a technically-sophisticated, neutral review group which is charged with rendering a final evaluation. Such a process was undertaken in 1982 to decide which of the advanced processes--AVLIS, MLIS, or PSP--should be selected to go forward to the 1987 demonstration. It was a very successful process in which all of the issues--technical, cost, and schedule--were fully delineated and resolved to within a narrowly defined level of uncertainty. I believe it is even more important to conduct such a rigorous evaluation for the 1985 selection as it will determine for decades to come the course of uranium enrichment in the United States.

If I can be of further assistance in this matter, please do not hesitate to call.

Sincerely,

Roger E. Batzel
Director

REB:wm

cc: Mr. Shelby T. Brewer
Mr. John R. Longenecker

AiResearch Manufacturing Company
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TORRANCE
CALIFORNIA 90509
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Twx: 910-346-6729 Telex: 67-4490

March 15, 1984

The Honorable Marilyn Lloyd
U.S. House of Representatives
Committee on Science and Technology
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Lloyd:

In response to your letter of March 7, 1984, attached are answers to the additional questions posed in your letter and as follow-up to the February 28, 1984 hearings of your Subcommittee on Energy Research and Production. We have answered these questions as completely as possible and to the best of our ability, recognizing that our role as a centrifuge developer and manufacturer does not give us complete access to Department of Energy and to Union Carbide Corporation, Nuclear Division data on certain elements of enterprise cost. On the other hand, our extensive history of involvement with the enterprise, totaling over 23 years, coupled with past Garrett initiatives pointed toward potential privatization of the enterprise does qualify us rather uniquely, I believe, to provide reasonable estimates in areas where we do not have DOE data.

Thank you again, Chairman Lloyd, for the opportunity of presenting testimony at your February 28 Subcommittee hearing. If we can provide any additional information, please do not hesitate to contact us.

Sincerely,

AIRESEARCH MANUFACTURING COMPANY

C. J. Rowan
Director
Enrichment Systems

LDH:lss
Enclosure

ADDITIONAL QUESTIONS FOR MR. ROWAN
Hearing on Uranium Enrichment
February 28, 1984

Question 1:

What do you calculate as the cost per SWU for Set III machines in both a two- and a four-building GCEP?

Answer:

The cost per SWU expressed in FY 1985 dollars for Set III machines is shown in Table 1. Consistent with normal industrial practice, interest costs are not included. The data is based on plant operation of 30 years at maximum capacity. The enterprise start-up phase is five and ten years, respectively for the two- and four-building cases. The matrix of Table 1 represents the cost of SWUs defined as follows:

1.	Steady State (without and with sunk costs)	Annual cost of operations (including amortization of plant and equipment) at maximum capacity; i.e., a one year "snapshot" at full capacity
2.	Total Enterprise (without and with sunk costs)	Average cost based on total capital, start-up, and operating cost over the project life

The SWU cost associated with the current plan of filling approximately half of Process Building 1 with Set III machines and retrofitting at a later date with Set V machines is shown on Table 2.

TABLE 1

SWU COST OF SET III MACHINES

	2 BUILDINGS		4 BUILDINGS	
	W/O SUNK COSTS	WITH SUNK COSTS	W/O SUNK COSTS	WITH SUNK COSTS
STEADY STATE	67	97	54	67
TOTAL ENTERPRISE	69	100	58	71

TABLE 2

SWU COST OF SET III/V MACHINES

	2 BUILDINGS		4 BUILDINGS	
	W/O SUNK COSTS	WITH SUNK COSTS	W/O SUNK COSTS	WITH SUNK COSTS
STEADY STATE	27	37	22	26
TOTAL ENTERPRISE	28	38	23	28

ADDITIONAL QUESTIONS FOR MR. ROWAN
Hearing on Uranium Enrichment
February 28, 1984

Question 2:

If we are not going to start production of Set V machines for a couple of years yet, why wouldn't it be cost-effective to shut down Set III production and restart manufacturing capability anew on Set V machines?

Answer:

It is more cost effective to continue Set III production than to shut down and restart. To terminate production now would cost more than the two years of production and short the program 800 machines from each CM.

Garrett's Cost to Terminate and Restart ($ Millions)		
Interrupt Production		52.0
Program maintenance cost (fixed overheads)	10.0	
Storage cost	4.0	
Nucleus of program personnel	7.0	
Cancellation charges	31.0	
Restart Production		53.0
Personnel hiring and training	20.0	
Production line reactivation	30.0	
Vendor base redevelopment	3.0	
TOTAL		105.0

Therefore, the average cost to interrput is $52.5 million/year ($105.0 million divided by two years) while the cost to continue production is $40 million/year.

Further, the 800 machines could produce about 160,000 SWUs during this two year period, representing potential revenues of $21.6 million @ the current $135/SWU DOE price. They would continue to produce 160,000 SWUs/year, or $21.6 million per year of revenues.

Answer to Question 2 (cont):

In addition to the cost effectivity issue, a production interrupt would have significant impact on the enterprise. It might signal an end to GCEP. Who would support the AGC development? Would anybody stay in the game?

A production interrupt would also undermine DOE's efforts in marketing their new utility services contract. It would be a signal to the utilities to look elsewhere for enriching services.

The effect of a production interrupt would also have a negative impact on any privatization and/or off-budget initiatives and does not serve national energy sufficiency and security goals.

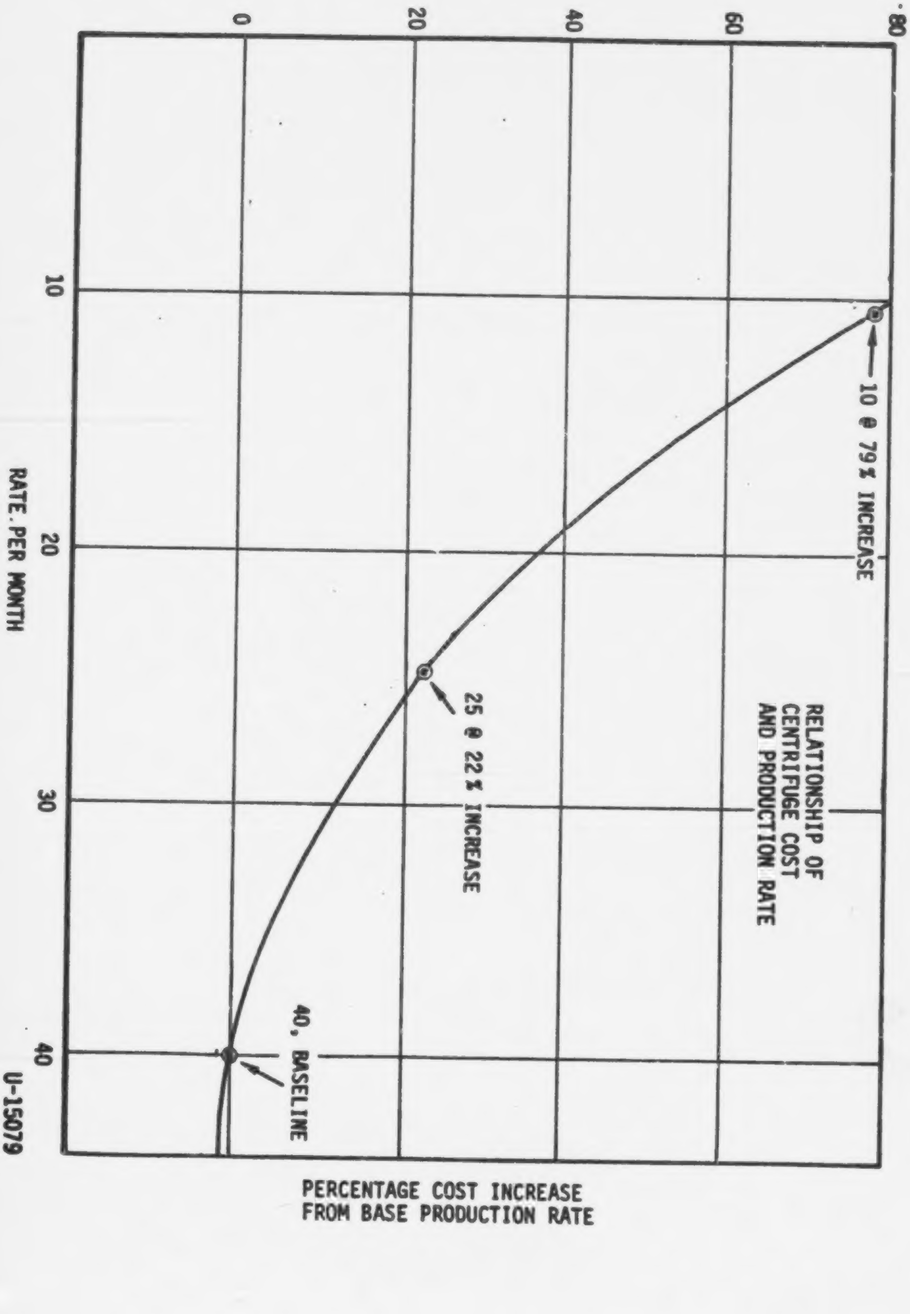
Any significant truncation of effort on GCEP seems inconsistent with the $2 billion in sunk cost. Would GCEP appear irresponsibly abandoned?

Question 3:

What is the unit cost for the purchase of 25 machines per month from each vendor? What would the unit cost be for the purchase of only ten machines each? Please comment on the manufacturing "learning curve," and provide a graph, if available, of unit cost plotted against the number of machines purchased.

Answer:

The relationship of centrifuge cost and monthly production rate for the Phase 1 production is shown on the attached "learning curve" or, more properly, quantity-variance curve.


RELATIONSHIP OF CENTRIFUGE COST AND PRODUCTION RATE
10 @ 79% INCREASE
25 @ 22% INCREASE
40, BASELINE
0
20
40
60
80
10
20
30
40
RATE PER MONTH
PERCENTAGE COST INCREASE FROM BASE PRODUCTION RATE
U-15079

ADDITIONAL QUESTIONS FOR MR. ROWAN
Hearing on Uranium Enrichment
February 28, 1984

Question 4:

What will you be doing with the proposed funding in advanced machine work?

Answer:

AMC has 23 years of success in full machine dynamics gas centrifuge experience which has earned us the responsibility for concept, analysis, design, development, testing, and demonstration of the following:

- High Speed End Caps
- Centrifuge Rotor Dynamics Control Culminating in Advanced Suspensions
- Development of Two Rotor Concepts
- Support Activities for Reliability, Cost Modeling, Producibility, Qualification, Machine Design, and Design Evaluation Testing

Question 5:

Please identify with as much specificity as is possible what additional activities would be conducted if $10 million were added to the advanced centrifuge program in FY 1985. Please explain the need and value of these activities.

Answer:

At this time, primary emphasis is on a single rotor suspension concept, which will provide a demonstration of the AGC performance objectives by the spring of 1985.

AMC could effectively utilize $4 million additonal FY 1985 funds for advanced suspension and high speed rotor development. The additional funding for advanced suspension would permit bringing a highly encouraging alternate suspension to prequalification status. This advanced suspension is potentially capable of providing substantial separative work (SWU) growth to the gas centrifuge (significantly beyond the current 600 SWU/yr/machine goal for Set V). The work with high speed rotors would optimize high speed end caps to further increase the performance potential of the AGC machine. These factors can provide additional competitive advantage for the U.S. enrichment enterprise.

ADDITIONAL QUESTIONS FOR MR. ROWAN
Hearing on Uranium Enrichment
February 28, 1984

Question 6:

How many people do you presently have employed on production of Set III machines? How many will you have in FY 1985?

Answer:

There are currently 397 "equivalent" people employed on the production of Set III machines. The monthly production rates of the level load schedule with FY 1985 funding of $40 million will result in the reduction of 25 personnel.

Question 7:

How many people do you have employed in advanced machine work? How many will you have in FY 1985?

Answer:

AiResearch currently employs 256 "equivalent" people in the machine development area; this quantity will be reduced by 78 during FY 1985, given the planned task and budget distribution.

Question 8:

You stated during the hearing that Garrett has about 1,000 people employed on centrifuge technology. Does this number include people hired by others to supply parts to Garrett? If not, why does Garrett have about 600 people more than Boeing on direct hire?

Answer:

The total of 1,000 people does not include vendor headcount. In addition to the tasks that we are performing under contract to DOE as a commercial centrifuge manufacturer and as an AGC developer, we also support DOE by providing engineering and technical support services for the GCEP plant, including the recycle/assembly facility and the production Set III centrifuge.

ADDITIONAL QUESTIONS FOR MR. ROWAN
Hearing on Uranium Enrichment
February 28, 1984

Question 9a:

What do you view as the chief deficiencies in the AVLIS technology, it being your only competition?

Answer:

In the LLNL testimony to the Subcommittee, it was stated that no significant technical problems existed on AVLIS, and that the only remaining issues are the cost of separative work and the uncertainties in cost. Considering the fact that the AVLIS process is currently in the predemonstration laboratory phase, that experiments to date have been done on individual system elements rather than a totaly integrated system, that a much simpler form of collector/extractor has been used than is planned in the production process, and that equipment tested has been substantially less than production scale, this appears to be at best an oversimplification. We understand for example that AVLIS experiments to date have resulted in the enrichment of uranium corresponding to substantially less than one separative work unit (SWU) as compared to over 70,000 SWUs already produced by Set III centrifuges. The deficiencies of AVLIS will manifest themselves as the process develops from this current predemonstration laboratory phase to laboratory scale integrated experiments, engineering development, full-scale process development, and plant implementation. While it is difficult to predict the details of AVLIS deficiencies which will manifest themselves during this evolution, we are convinced that they will be significant.

For example, we foresee the potential for significant problems in the stability of operation of the collector/extractor portion of the system and its scaling to full-size. In the field of plasma physics, more specifically in the study of collective behavior on ensembles of charged and neutral particles, it has been clearly established that stability criteria and scaling laws of plasmas are not well understood, as witness the extended development cycle for magnetically confined, controlled thermonuclear fusion, still far from complete.

In addition to the deficiencies bearing on collector scaling and the potential plasma physics related problems, other areas of potential deficiencies include: (1) solid uranium feedstock; (2) thermal management and control; (3) interrelationship between module thermal stability, optical alignment stability, and laser optical mode quality; (4) potential laser beam degradation; (5) AVLIS infrastructure/vendor base development.

ADDITIONAL QUESTIONS FOR MR. ROWAN
Hearing on Uranium Enrichment
February 28, 1984

Question 9b:

Should we rely on the unit cost of production now projected for AVLIS technology?

Answer:

No, primarily for the reasons cited above. There are significant areas of uncertainty in the AVLIS process definition without full-scale demonstration at process plant conditions. A feasible production system probably cannot be defined today without enormous uncertainties relating to subsystem and/or component interplay. Therefore, AVLIS cost projections are subject to large cost variance and have the potential for sizable cost growth. The cost uncertainties currently projected are based on relatively minor deviations from the present baseline design, when there is, in fact, no compelling reason to believe that the baseline design will work at full scale/full power conditions. In fact, a recent DOE-sponsored study at RAND Corporation supports that contention, since it concluded that cost growth and performance shortfalls in process plant projects are greatly increased when the project is not well defined, the technology has many new elements, and the materials are solids, all characteristic of AVLIS.

MINORITY QUESTIONS

Question 1:

What amount of R&D is necessary to make Set V procurement competitive, and when?

Answer:

The majority of Set V centrifuge R&D necessary for competitive procurement package definition will be complete by mid-FY 1985. This is consistent with DOE's plan of May, 1985 for selection between the Advanced Gas Centrifuge (AGC) and Atomic Vapor Laser Isotope Separation (AVLIS). AiResearch would be prepared to bid on a competitive procurement for Set V machines any time after that point; however, based on the present DOE procurement plan, a ramp-up to higher production rates would not occur until the 1989/1990 time frame, making that the most logical time for a fixed-price competitive procurement.

Question 2:

On what basis do you endorse a 4-building GCEP plant as opposed to 2, 6, or 8?

Answer:

My testimony supported DOE's current plan of a four-building GCEP incorporating Set V centrifuges following the fill of the first one half process building with Set III machines. Since the original design of the GCEP complex was based on eight process buildings, including the configuration of the recycle/assembly building, the completion of less than four process buildings would represent a very inefficient use of the complex and would not adequately capitalize on economies of scale. On the other hand, the substantial improvement in separative work capability of the Set V machine, that is, three times the performance of the Set III machines, means that a four-building GCEP, following retrofit of the one half process building of Set III machines, will provide a total separative work capacity of 13.2 million SWUs per year. I believe that this would represent a reasonably efficient plant size and be consistent with DOE's goal of reducing the price of separative work substantially in the late 1980's and early 1990's. Construction of process buildings five through eight could then be carried out on a schedule consistent with developing market demand and a reasonable corresponding schedule of turning down the existing gaseous diffusion plants.

MINORITY QUESTIONS (cont)

Question 3a:

How appropriate is an FY 1985 definitive evaluation of the advanced gas centrifuge process versus the laser isotope separation process?

Answer:

As indicated in their testimony, DOE plans to select an advanced technology between AGC and AVLIS by May of 1985 for subsequent implementation is driven in part by the lack of sufficient funds to continue full-scale development of both technologies. The AGC program is presently structured to provide DOE with all the necessary data, both analytical and test, to support a decision in that time frame.

It is our understanding that the AVLIS program is proceeding under DOE direction to similarly have available the necessary analytical and test data to support a May, 1985 decision, and have so testified both at Chairman Lloyd's Subcommittee hearings as well as those of the Energy Conservation and Power Subcommittee of House Energy and Commerce.

Should AGC be chosen over AVLIS in May of 1985 based on its economics, its status as a logical evolution of the proven Set III centrifuge, its more advanced demonstration status, and its well-developed infrastructure and extensive cleared vendor base, we understand that DOE does intend to continue limited R&D for AVLIS application to the uranium enrichment enterprise. Additionally, we would assume that AVLIS would continue to be funded from other sources for its defense application in plutonium separation; thus it would still be available for possible process implementation in the more distant future at such time as its currently very uncertain economics are better proven.

Question 3b:

By the end of that year, and under presently planned rates how much production will have been accomplished by the two processes?

Answer:

A further measure of the readiness of the centrifuge process is its projected SWU production over the period of interest. By May of 1985, the Set III centrifuges will have produced over 100,000 SWUs; the Set V machine will have produced approximately 2,000 SWUs. We understand that to date the AVLIS process has produced substantially less than one separative work unit. We have insufficient information to make a reasonable estimate of AVLIS separative work production by May of 1985.

BOEING ENGINEERING & CONSTRUCTION SOUTHEAST, INC.
OAK RIDGE, TENNESSEE 37830

RICHARD L. GRANT
PRESIDENT AND
EXECUTIVE DIRECTOR

MAR 19 1984

March 13, 1984

Dear Chairman Lloyd:

The attached information is in response to the additional questions posed in your letter of March 7, 1984. In each case, the questions are answered the best my knowledge base will permit and represent my own assessment of the facts surrounding each question.

I appreciate the opportunity to respond and hope the information will be useful to you.

Sincerely,

The Honorable Marilyn Lloyd
House of Representatives
Rayburn House Office Building
Washington, D. C. 20515

Enclosure:
as stated

A SUBSIDIARY OF THE BOEING COMPANY

Question 1: What do you calculate as the cost per SWU for SET III Machines in both a two- and a four-building GCEP?

RESPONSE: My response is based on the costs assigned to capital and operating expenditures. In each case the enterprise is assumed to persist for 30 years at maximum capacity for the two- or four-building enterprise with the on-line schedules as shown. All dollars are FY1985.

Two-building GCEP

Year	Capacity
1986	0.5 M/SWU
1987	0.9 "
1988	1.3 "
1989	1.6 "
1990	1.9 "
1991	2.2 "
1992 & on	2.2 "

Total Enterprise Production = 72.2 M/SWU

Capital Expenditure
Total = $4.0B
Incremental
(FY 1985 forward) = $1.7B

Steady State Operating Costs	
Replacement Hdw.	$44M/Yr
Personnel *	28M/yr
Power & all other	15M/Yr
Total	*87M/Yr

or $39.55/SWU

Start Up Years Cost
1986 through 1991 - $370M

Total Enterprise Cost	
Operating & Startup	$2980M
Capital -Total	4000M
Sum	$6980M

Cost/SWU = $96.68

Incremental Enterprise Cost	
Operating & Startup =	$2980M
Capital-Incremental	1700M
Sum	$4680M

Cost/SWU = $64.81

Four-Building GCEP

Year	Capacity
1986	0.5 M/SWU
1987	0.9 "
1988	1.3 "
1989	1.6 "
1990	1.9 "
1991	2.2 "
1992	2.6 "
1993	3.1 "
1994	3.7 "
1995 & on	4.4 "

Total Enterprise Production - 149.8 M/SWU

Capital Expenditure
Total = $5.3B
Incremental (FY 1985 forward)
= 3.0B

Steady State Operating Costs	
Replacement Hdw	$82M/Yr
Personnel *	53M/Yr
Power and all other	30M/Yr
Total	$165M/Yr

or $37.50/SWU

Start up Years Cost
1986 through 1994 = $720M

Total Enterprise Cost	
Operating & Startup	$5670M
Capital -Total	5300M
Sum	$10970M

Cost/SWU = $73.23

Incremental Enterprise Cost	
Operating & Startup =	$5670M
Capital-Incremental	3000M
Sum	$8670M

Cost/SWU = $57.88

None of the above include interest on the capital, only repayment of the capital. Interest at whatever rate one wishes to assume would be additive if appropriate. Inflation is also not included in any way and could be added as deemed appropriate.

* Including Gaseous Diffusion Plant Support

Question 2: If we are not going to start production of Set V machines for a couple of years yet, why wouldn't it be cost-effective to shut down Set III Production and restart manufacturing capability anew on Set V machines?

RESPONSE: Assuming that the centrifuge production capability is needed at sometime in the future, the cost of putting the production on hold consists of the cost of terminating and preserving the facilities and equipment, the fixed costs which are time dependent only and the restart costs which are made up of the reactivation costs, training costs, vendor base re-establishment costs and the loss of the learning curve.

The termination and holding costs will range between $110M and $150M depending on the duration of the "hold." The reactivation costs will range from $160M to $200M depending on the number of units of production to be fabricated after restart.

These costs are for centrifuge manufacturers only. I am not in a position to comment on other costs to the program.

Question 3: What is the unit cost for the purchase of 25 machines per month from each vendor? What would the unit cost be for the purchase of only ten machines each? Please comment on the manufacturing "learning curve," and provide a graph, if available, of unit cost plotted against the number of machines purchased.

RESPONSE: The best available response to this question is in terms of the ratio of costs to those presently being experienced. If we assume the present production rate to produce a machine cost of 1.0, reduction to 25 machines per month will increase the unit cost to about 1.2. At ten machines per month, this cost will go to about 1.5. I have previously provided a treatise on learning curves to the committee staff. The attached curve is from that treatise. The curve shown will very closely approximate the cost history being experienced on the program today and the cost as a function of units purchased.

Question 4: What will you be doing with the proposed funding in advanced machine work?

RESPONSE: Our role on the AGC Program is to develop and qualify the advanced materials, to design fabricate and test upper suspensions, rotors, scoops, lower suspensions and other ancillary hardware. We will be running Set V Prototypes on Uranium hexafloride gas and demonstrating enrichment beyond what was already demonstrated in 1983 and early 1984.

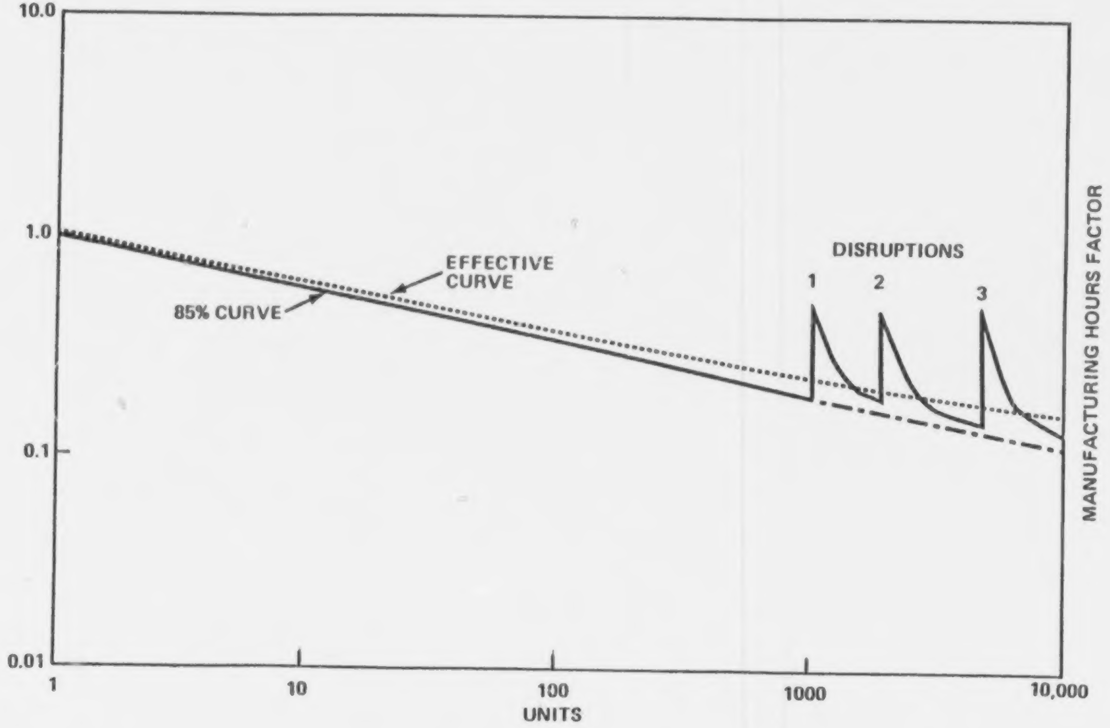

10.0
1.0
0.1
0.01
1
10
100
1000
10,000
UNITS
MANUFACTURING HOURS FACTOR
EFFECTIVE CURVE
85% CURVE
DISRUPTIONS
1
2
3

FIGURE 4

Question 5: Please identify with as much specificity as is possible what additional activities would be conducted if $10 million were added to the advanced centrifuge program in FY1985. Please explain the need and value of these activities.

RESPONSE: If $10 million were added to AGC funding, I assume that about $3M would be available to Boeing. More aggressive programs in each of the areas identified in Response to Question 4 above would be mounted along with more definitive design specification development. No totally new initiative would result.

Question 6: How many people do you presently have employed on production of Set III Machines? How many will you have in FY 1985?

RESPONSE: Present employment on Set III Production is 334 people. This number will reduce only slightly in FY1985 if the $40M funding is preserved. A few people will be reduced due to learning curve improvements but this will all come from attrition.

Question 7: How many people do you have employed in advanced machine work? How many will you have in FY 1985?

RESPONSE: Present employment on Set V work is 80 people. FY 1985, up to selection, will employ about 105 people. 10 to 15 people would be added for each $1M in additional funding.

MINORITY QUESTIONS:

Question 1: What amount of R&D is necessary to make Set V Machine procurement competitive, and when?

RESPONSE: Competitive Set V machine procurement can proceed whenever the design has been firmed up. As a practical matter the best, earliest time for this would be in early calendar year 1986. Boeing is prepared to enter into a competitive environment at DOE's pleasure.

Question 2: On what basis do you endorse a 4-building GCEP plant, as opposed to 2, 6 or 8?

RESPONSE: My endorsement of a four-building GCEP is based on the fact that the most practical near-term program of a scale which can take some advantage of the design and costs already incurred for an eight-building GCEP is this size. Clearly, a 6-or 8-building GCEP would maximize the economies of scale and produce the lowest cost product. However, the great success of Set V suggests that the production capability of a 6-or 8-building GCEP may not be needed for a long time. Set V production capability for these sizes is as follows:

2 building - 6.6M SWU/Yr
4 building - 13.2M SWU/Yr
6 building - 19.8M SWU/Yr
8 building - 26.4M SWU/Yr

Quesiont 3: How appropriate is an FY 1985 definitive evaluation of the advanced gas centrifuge process versus the laser isotope separation process?

By the end of that year, and under presently planned rates, how much production will have been accomplished by the two processes?

RESPONSE: The appropriate timeframe for comparison of the two processes is being driven by pressures to maximize the confidence of proceeding within the near-term revenues while assuming that the failure of either advanced process would not eliminate options for improving the overall enrichment enterprise. It seems reasonable that applying all available R&D resources to one process is likely to improve confidence both in schedule and success. Balancing the risk of a wrong decision and its subsequent impact on the enterprise is a difficult task. It is, however, my opinion that competent assessment and realistic assignment of uncertainty can produce a rational evaluation in the proposal time period.

It is difficult for me to determine how much enriched uranium at what assay may have actually been produced with the AVLIS process or how much will be actually produced by the planned selection date. However, the Set V prototypes will have produced a few 10's of grams of actual enriched product.

GOODYEAR AEROSPACE
CORPORATION
AKRON, OHIO 44315

March 13, 1984

U.S. House of Representatives
Committee on Science & Technology
Subcommittee on Energy Research & Production
Room B-734 Rayburn House Office Building
Washington, D.C. 20515

ATTENTION MS. DEBBIE MARTIN

Subject: Hearing on Uranium Enrichment February 28, 1984--Supplemental Data for Hearing Record

Reference: (a) Letter of 3/7/84 to Dr. E.O. Hartig (GAC) from Marilyn Lloyd, Chairman, Subcommittee on Energy Research & Production

Dear Ms. Martin:

In response to the reference (a) letter, Goodyear Aerospace Corporation respectfully submits our answers to the questions tendered therein as follows:

Q: WHAT DO YOU CALCULATE AS THE COST PER SWU FOR SET III MACHINES IN BOTH A TWO AND A FOUR BUILDING CONCEPT?

A: Given the rapid progress being made in the development of the Set V machine, we believe it is realistic and prudent to incorporate Set V machines in half of the second building, with Set III machines in 1-1/2 buildings. The incre-mental cost per SWU in FY-85 dollars for two buildings thus equipped are calculated to be:

	Thru Yr. 2005 14 yrs. full production	Thru Yr. 2016 25 yrs. full production
Cost/SWU	$87	$69

These costs include development and start-up costs for Set V machines.

Additional buildings should have all Set V machines, thereby providing further dramatic reduction in SWU costs.

Q: IF WE ARE NOT GOING TO START PRODUCTION OF SET V MACHINES FOR A COUPLE OF YEARS YET, WHY WOULDN'T IT BE COST-EFFECTIVE TO SHUT DOWN SET III PRODUCTION AND RESTART MANUFACTURING CAPABILITY ANEW ON SET V MACHINES?

A: We believe it would cost more to shut down and restart, than it would to continue Set III production, as shown here:

	$ Millions
A. Cost of Set III production for two years	$ 80
B. Cost of termination and restart	
Terminate current contract	$ 40
Two years standby	20
Restart, including learning	60
	$120

In addition, the lost value of 240,000 SWU's produced by operating the Set III machines manufactured in two years, is also an important consideration. At the current DOE selling price of $135/SWU, this is worth $32,400,000.

The above estimates apply to our operations. We assume each of the other centrifuge manufacturers would have similar costs.

There are also other important considerations relating to shutting down Set III production:

- Continued production will avoid the loss of 400 jobs in our plant and 200 jobs at our suppliers. We assume similar impacts for other GCEP participants.
- Start-up of GCEP with Set V machines will be delayed perhaps two years, because of the added time required to start-up again and regain learning. This means U.S. consumers will not realize the benefits of reduced SWU costs until this later time, and we will continue to lose more domestic and international market share to foreign competition.
- It is not evident that Goodyear Aerospace or the other CM's are willing to revert to a standby mode for two years. We may wish to use our facilities for other more profitable business opportunities, rather than have them in a non-productive standby mode where we do little more than recover our costs.

Q: WHAT IS THE UNIT COST FOR THE PURCHASE OF 25 MACHINES PER MONTH FROM EACH VENDOR? WHAT WOULD THE UNIT COST BE FOR THE PURCHASE OF ONLY TEN MACHINES EACH? PLEASE COMMENT ON THE MANUFACTURING "LEARNING CURVE," AND PROVIDE A GRAPH, IF AVAILABLE, OF UNIT COST PLOTTED AGAINST THE NUMBER OF MACHINES PURCHASED.

A: See attached graph.

Q: WHAT WILL YOU BE DOING WITH THE PROPOSED FUNDING IN ADVANCED MACHINE WORK?

A: Goodyear has the responsibility for concept analysis, development, design, testing and demonstration of the following:

- Set V rotor assembly of GAC's unique advanced materials.
- Set V column assembly.
- Gas dynamic analysis.
- Gas flow management, including related centrifuge components.

Q: PLEASE IDENTIFY WITH AS MUCH SPECIFICITY AS IS POSSIBLE WHAT ADDITIONAL ACTIVITIES WOULD BE CONDUCTED IF $10 MILLION WERE ADDED TO THE ADVANCED CENTRIFUGE PROGRAM IN FY 1985. PLEASE EXPLAIN THE NEED AND VALUE OF THESE ACTIVITIES.

A: From the increased funding in FY-85, Goodyear would effectively utilize $1-1/2 to 2M to improve Set V rotor design to provide for 5-stream operation, increase producibility, and improve ease of balancing. Improved flow management concepts, components and testing will be included.

Q: HOW MANY PEOPLE DO YOU PRESENTLY HAVE EMPLOYED ON PRODUCTION OF SET III MACHINES? HOW MANY WILL YOU HAVE IN FY 1985?

A: We currently have approximately 435 people employed on Set III machines. We estimate we will have approximately 400 people employed on Set III machines in FY-85 based on the level load schedule.

Q: HOW MANY PEOPLE DO YOU HAVE EMPLOYED IN ADVANCED MACHINE WORK? HOW MANY WILL YOU HAVE IN FY-1985?

A: We have approximately seventy people employed in advanced machine work. We project approximately sixty-five people will be employed on advanced machine work in FY-85.

Q: WHAT AMOUNT OF R&D IS NECESSARY TO MAKE SET V MACHINE PROCUREMENT COMPETITIVE, AND WHEN?

A: It is assumed the question means "competitive between the Centrifuge Manufacturers." The Set V machine development must have proceeded through the following stages for competitive procurement:

- Completion of development and testing including value engineering and process development required to achieve the CDR (critical design review) milestone at end FY-1985.
- Completion of the Set V design package with all component and subassembly design and specifications by FY-86.

- Sufficient whole Set V machine reliability testing to assure acceptable GCEP operation. This Set V machine production and testing is planned in FY-86 continuing in FY-87 to support the planned FY-87 RFP date.

Q: ON WHAT BASIS DO YOU ENDORSE A 4-BUILDING GCEP PLANT, AS OPPOSED TO 2, 6 OR 8?

A: It was not my intent to convey an "endorsement" of a 4-building GCEP plant versus 6 or 8. My words were "a minimum four building GCEP complex." A 6- or 8-building complex is certainly more cost-effective than 4, and would provide additional cost benefits to U.S. consumers, provide more job security for U.S. workers and diminish our dependency on foreign energy sources through the inroads of foreign competition. A 4-building plant has the same advantages over a 2-building plant.

I recommended a minimum 4-building complex because recent, I suspect pessimistic, DOE forecasts indicate additional capacity may not be justified at this time. I also stated "An early decision should be made to add capacity as soon as DOE can confidently project its market base."

Q: HOW APPROPRIATE IS A FY-1985 DEFINITIVE EVALUATION OF THE ADVANCED GAS CENTRIFUGE PROCESS VERSUS THE LASER ISOTOPE SEPARATION PROCESS?

A: We are confident sufficient data will be available on the performance and economics of both AGC and AVLIS processes to enable DOE to perform a definitive evaluation and make a sound decision in mid FY-85. An AVLIS representative took this same position in recent testimony before this Subcommittee.

Q: BY THE END OF THAT YEAR, AND UNDER PRESENTLY PLANNED RATES, HOW MUCH PRODUCTION WILL HAVE BEEN ACCOMPLISHED BY THE TWO PROCESSES?

A: Gas Centrifuge Process

o AETF		20,000 SWU's*
o CPDF 2,762 SWU's/Mo.	49,716 SWU's thru 2/84 52,478 SWU's 3/84 to 9/85	
	Total (CPDF)	102,194 SWU's
o GCEP (Set III)—first train Sept. 85, therefore, no SWU's in FY-85.		-0-
o AGC--475 SWU's (GAC only). It is estimated other participants will have produced approximately 1,500 SWU's.		1,975 SWU's
	Grand Total	124,169 SWU's

*This is an estimate of the total SWU from all AETF testing.

AVLIS—We estimate that the AVLIS process will have produced approximately 1/2 SWU by end FY-1984. Not knowing the detail of their FY-1985 plans, we cannot estimate their production.

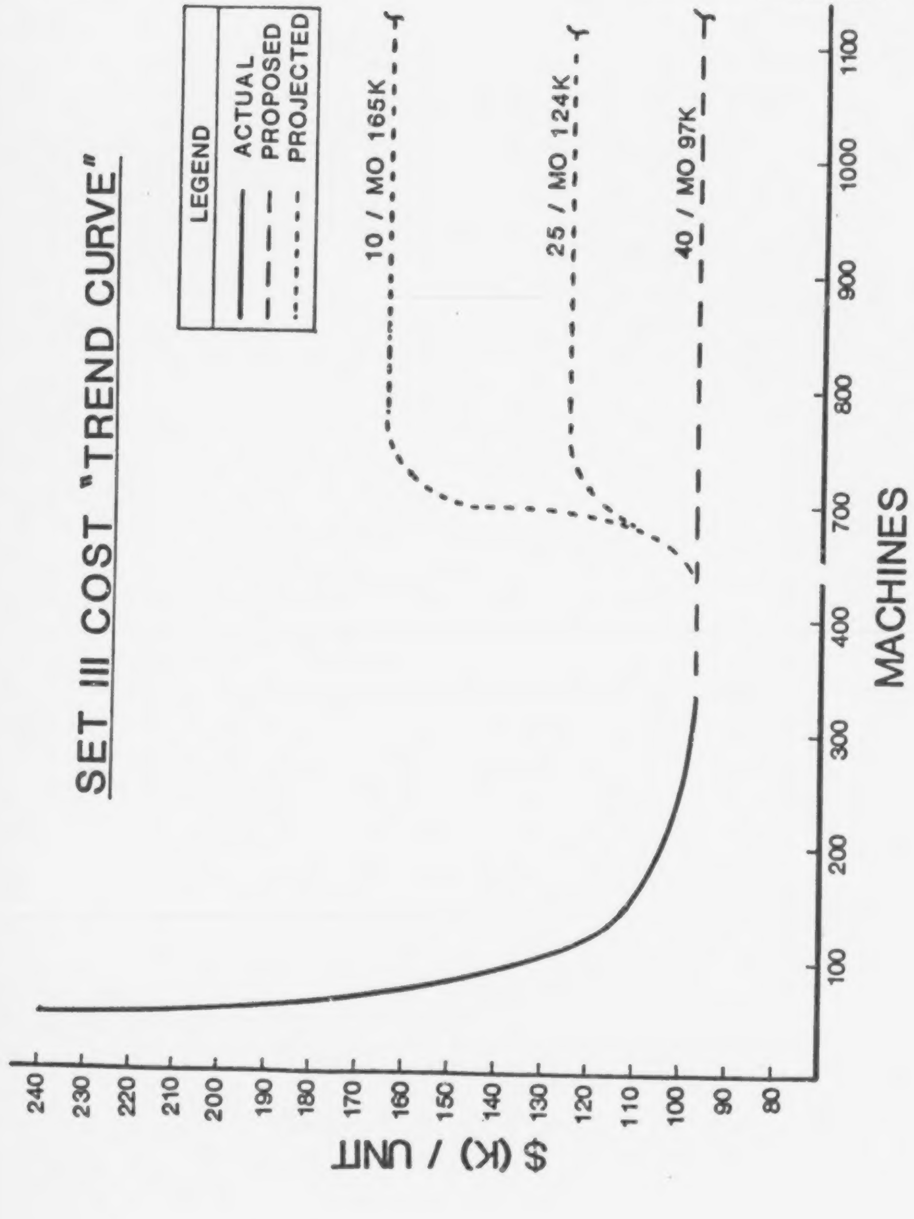
Sincerely,

GOODYEAR AEROSPACE CORPORATION
Centrifuge Equipment Division

J. C. Feldscher, Manager
Business and Economics

JCF/lg

RESPONSE TO QUESTION NO. 3



SET III COST "TREND CURVE"

LAWRENCE LIVERMORE LABORATORY

March 14, 1984

The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy
Research and Production

Dear Ms. Lloyd,

Thank you for the opportunity to testify at your February 28, 1984 Subcommittee hearings on the Department of Energy's Uranium Enrichment program.

My response to the questions in your letter of March 7, 1984 is given in the attachment. I hope that the material provides a useful supplement to the record of the hearing.

Sincerely,

John L. Emmett

John L. Emmett
Associate Director for Lasers

JE/wo
Attachment

University of California P.O. Box 808 Livermore, California 94550 □ Telephone (415) 422-1100 □ Twx 910-386-8339 UCLL LVMR

ADDITIONAL QUESTIONS FOR DR. EMMETT
Hearing on Uranium Enrichment
February 28, 1984

- *How much will Lawrence Livermore National Laboratory receive for AVLIS development in FY85?*

The total (President's) budget for the National AVLIS program(s) in FY85 is as follows ($ millions):

	Uranium	Plutonium
Operating	69.8	30.0
Equipment	8.2	9.0
Totals	78.0	39.0

Of these totals, the Lawrence Livermore National Laboratory will receive approximately the following:

	Uranium	Plutonium
Operating	55.5	25.0
Equipment	4.5	9.0
Totals	60.0	34.0

- *How do you know that an AVLIS plant will be reliable?*

The AVLIS process utilizes equipment having very high productivity per operating cycle. This high productivity means that relatively short (<1 yr) lifetimes for all special equipment are compatible with low cost SWU production (∿$20/SWU). The lifetesting we have done to date (or are planning to complete within the next year) will verify reliable operation up to approximately 20 percent of the production lifecycles required to achieve our economic goals. Due to the limited time available, we cannot achieve more extensive operational experience prior to mid FY85. However, as a fraction of what needs to be accomplished, we believe the AVLIS lifetest data will be adequate to support reliability projections for production. The AVLIS plant designs utilize component redundancy to achieve high production reliability.

- *What do you believe are the chief deficiencies of advanced centrifuge technology, it being your only competition?*

The gas centrifuge program was until recently conceived of as eight process buildings fitted with Set III machines each having a capacity of 200 SWU/y. The total production capacity of GCEP was to be approximately 8.8 Million SWU/y, requiring approximately 44,000 centrifuge machines. The cost of this project in todays dollars is about $8.8 billion so that capital costs alone would exceed $100/SWU. When operating costs are included the total production costs would exceed $125/SWU. Because of this high production cost, the AGC program and the Set V centrifuge has been conceived but not demonstrated. The proposal here is to design a machine which could produce 600 SWU/y and could be manufactured for the same cost as the Set III machine. Thus, one could produce 26.4 million SWU/y from the same $8.8 billion production complex, yielding a production cost ∿$40-60/SWU.

The estimated cost for a comparable 26.4 million SWU/y production complex utilizing AVLIS is approximately $2.4 billion in todays dollars. When operating costs are included, this yields an AVLIS production cost of $15-$30/SWU. Quite simply, the chief deficiency in the advanced centrifuge program is that, even if it is technically successful, it is not economically competitive and the deployment costs are excessively high.

- *What would you do differently in the development of your technologies if you were managing the entire enrichment complex?*

The enrichment enterprise is faced with a classic business problem, viz., transition from an old technology to a new technology. Those who fail in this situation often do so because they continue to pursue an old technology, hoping to avoid technical risk by continuing to make financial investments in old technology with little potential for improvement. The best decisions are those that accept technical risks compatible with financial rewards. The radical difference (∿5X) in capital costs between gas centrifuge and AVLIS and the long-term potential of this new laser technology supports the contention that AVLIS should be the future focus of the uranium enrichment enterprise. The continuation of the gas centrifuge program may appear to be the safe approach in the short term, but it will obsolete the U.S. enterprise in the long term. I would make the hard decision today and focus resources on the high technology AVLIS approach in order to put the U.S. in a long-term leadership role.

- *Please identify with as much specificity as is possible what additional activities would be conducted if $20 million were added to the Atomic Vapor Laser Isotope Separation Program in FY 1985. Please explain the need and value of these activities.*

The AVLIS program is focussing all available resources on the mid FY85 selection date. In going from FY84 to FY85, the AVLIS budget is being reduced from approximately $103 million to $78 million. Whether we win or lose the process selection, the FY85 budget implies a rapid shutdown of the AVLIS program after the decision date. An additional $20 million would allow us to achieve or exceed the demonstration milestones prior to process selection and, at the same time, maintain staff levels at Oak Ridge and Livermore throughout the remainder of FY85 after process selection.

- *How appropriate is an FY 1985 definitive evaluation of the advanced gas centrifuge process versus the laser isotope separation process?*

  By the end of that year, and under presently planned rates, how much production will have been accomplished by the two processes?

The appropriateness of an FY85 definitive evaluation of the advanced gas centrifuge and AVLIS processes is dependent on the business conditions of the uranium enrichment enterprise. The gas centrifuge program will not have a full speed, full capacity advanced machine operating for significant time periods, nor will the AVLIS program have a full-scale separator and full-power laser operating within the next year. Since AVLIS has conducted literally hundreds of separation runs the risk associated with early process selection is financial rather than technical.

Based on the radical difference (∿5X) in capital cost between gas centrifuge and AVLIS and the long term technology potential, it appears that AVLIS can be selected with considerably less risk. Even with an improbable shortfall in AVLIS technical performance, the financial risks to the uranium enrichment enterprise would be minimized by an AVLIS selection.

UNION CARBIDE

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
P. O. BOX P, OAK RIDGE, TENNESSEE 37830

March 16, 1984

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Production
Committee on Science and Technology
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Attention: Ms. Debbie Martin

Dear Madam Chairman:

In response to your letter of March 7, 1984, I am enclosing answers to additional questions from the hearing on Uranium Enrichment, February 28, 1984.

Sincerely yours,

W. C. McWhorter, P3a Program Manager
Technical Integrator Program Office

WCM:LBA:ipc

Enclosures

cc: File - WCM - NoRC

ADDITIONAL QUESTIONS FOR MR. MCWHORTER
Hearing on Uranium Enrichment
February 28, 1984

- How much will Union Carbide receive for advanced centrifuge development?
- How do you know Set V technology will be reliable?
- What do you believe are the chief deficiencies of the AVLIS technology?
- What would you do differently in the development of centrifuge technology if you were managing the entire enrichment complex?
- Please identify with as much specificity as is possible what additional activities would be conducted if $10 million were added to the advanced centrifuge program in FY 1985. Please explain the need and value of these activities.

How much will Union Carbide receive for advanced centrifuge development?

As you know, Martin Marietta will replace Union Carbide Corporation Nuclear Division as the Oak Ridge operating contractor on April 1, 1984. In the FY 1985 proposed budget, approximately $21 million is allocated to development of the Advanced Gas Centrifuge (AGC) by Martin Marietta; these funds cover development of certain centrifuge components for which Martin Marietta is design agent, rotor materials evaluation, environmental and safety evaluation, machine design evaluation testing, machine qualification testing, machine aggressive failure testing for safety, reliability testing, and centrifuge performance measurements. An additional $8 million in FY 1985 is budgeted for AGC program management and other activities, including planning, quality assurance, and laboratory operations.

How do you know Set V technology will be reliable?

The principle difference between Set V centrifuges and previous designs is in the material used to construct the centrifuge rotor. A limited reliability and life of this material can be projected by mid FY-85 when the decision to demonstrate this technology will be made. By mid-FY-86 additional material and centrifuge testing will have given better information on early design problems and any modifications necessary will have been made to the design. In addition, more information will be available from component tests, which can be used to provide an improved extrapolation of machine lifetime. Reliability data will also be accumulated from Set V centrifuge operation. This will include data from development testing, which will have been under way since late 1984; from Set V centrifuges placed in reliability test in January 1987; and from Gas Centrifuge Enrichment Program deployment planned at a low level in the same time frame. A planned program of life-improvement during this low-level deployment period will provide a very desirable way to upgrade the Set V design if any changes are needed and will result in the achievement of overall life-cycle economic advantage and minimized cost of SWU production.

What do you believe are the chief deficiencies of the AVLIS technology?

The AVLIS program must demonstrate that the process will produce separative work when integrated from its components into a plant scale system. It must be developed from the present component prototype stage to a full-scale, integrated process with the rugged, reliable, and operable features which are so important in industrial processes. The transition to plant implementation typically requires some years for complex processes. As you know, the centrifuge process, which is relatively simple, has, over a number of years, evolved to a level of maturity which has allowed deployment in GCEP.

What would you do differently in the development of centrifuge technology if you were managing the entire enrichment complex?

I strongly support the recent Department of Energy changes which have been made in the enrichment program to emphasize customer involvement, reduction of SWU cost through the development of advanced separation processes, and implementation of sound business planning to establish program direction. It is my belief that this approach can lead to very beneficial results, including proper economic decisions relative to achieving the best return on the government investment in GCEP, as well as firm plans for achieving and maintaining a low SWU price for our customers.

Please identify with as much specificity as is possible what additional activities would be conducted if $10 million were added to the Advanced Centrifuge Program in FY 1985. Please explain the need and value of these activities.

High priority program needs for FY 1985 include about $3 million for parallel development of advanced rotor suspension concepts; about $3 million for backup hardware for component and full machine testing at Boeing, Goodyear Aerospace, AiResearch, and Martin Marietta; about $2 million for materials evaluation; and the balance of about $2 million for development work on other centrifuge components.

Additional funding for these activities would provide improved assurance that the development schedule can be maintained. During FY 1985, a very aggressive full centrifuge test program will be conducted by the program participants to select the design features for the production prototype design. The availability of resources to proceed with this work without reducing the scope of the technical approaches from the original program plan would serve to provide a greater confidence that the development program will be successful on schedule.

MINORITY QUESTIONS

- How appropriate is an FY 1985 definitive evaluation of the advanced gas centrifuge process versus the laser isotope separation process?

  By the end of that year, and under presently planned rates, how much production will have been accomplished by the two processes?

How appropriate is an FY 1985 definitive evaluation of the advanced gas centrifuge process versus the laser isotope separation process?

The AGC Program is scheduled to provide information by mid FY-85 on which a decision can be based to proceed process with the demonstration of Set V technology. Confidence to proceed will be based on the operation of full size development centrifuges which will address the adequacy of the centrifuge design features necessary to achieve the increased centrifuge rotor speed and a resulting SWU output of approximately three times the initial GCEP centrifuge. If, at this time, either the AGC Program or the AVLIS Program has encountered technical obstacles which result in missing data, a deferral in the decision to select and demonstrate either technology would be appropriate so that a high-quality decision could be made for the process selection.

By the end of the year, and under presently planned rates, how much production will have been accomplished by the two processes?

We project that the initial GCEP type centrifuges (Set III) will have produced about 140,000 SWU through the end of FY 1985. In addition, about 2,000 SWU will have been produced by the Set V centrifuges incidental to centrifuge development testing. This output is normally not recovered, as testing modes usually involve recycle of the UF_6 gas stream through the test machines.

	STATUS		CUMULATIVE COST FY-84 THRU - ($ M)
MID FY-85	● LIMITED HI-SPEED TESTING ● CANDIDATE SET V SELECTED	● PERFORMANCE GOALS VALIDATED ● COSTS BOUNDED REASONABLY WELL ● LIFETIME EXTRAPOLATED	125
MID FY-86	● HI-SPEED SEPARATION PERFORMANCE DEMONSTRATED	● PERFORMANCE DEMONSTRATED ● COSTS IMPROVED THROUGH ADDITIONAL INFORMATION ● LIFETIME EXTRAPOLATED, BETTER INFORMATION ON EARLY PROBLEMS	190
MID FY-87	● MULTI-MACHINE RELIABILITY TEST STARTED ● MULTIPLE MACHINE PRODUCTION EXPERIENCE	● PERFORMANCE DEMONSTRATED ● COSTS WELL ESTABLISHED THROUGH MANUFACTURING ● LIFETIME DATA BEING ACCUMULATED	265

Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

March 13, 1984

Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Production
Room B-734 Rayburn House Office
Building
Washington, D. C. 20515

Dear Congresswoman Lloyd:

This is in response to the five additional questions raised in your March 7, 1984 letter to me.

1. **Commonwealth Edison (CE) has reportedly announced its intent to convert all of its 15 enrichment contracts with the DOE to the new Utility Services Contract. What percentage of CE's enrichment needs will be committed to DOE supply? What was the major factor in CE's decision to convert?**

Commonwealth Edison is still in the process of determining the percentage of its enrichment needs to be committed to DOE supply. As you may be aware, we have solicited bids for our requirements above 70% and are in the process of evaluating those bids at present. Influencing our decision to convert is the fact that the U.S. Contract offers the supply flexibility we require along with favorable economics and supply assurance.

2. **Does EEI have a position on the need for deploying advanced technologies for enrichment, and if so, what is it?**

Based on the data available to us, we believe that advanced technologies are necessary in order to contain the costs of enrichment and to keep the U.S. enrichment establishment competitive. Because of the classified nature of the work being performed on advanced technologies, our knowledge in this area is limited and as we indicated during the hearing we request the opportunity to participate in the decisionmaking process with respect to the technologies to be deployed.

3. **Do you believe that it is a wise business position to finance capital expansion projects only through current income, as DOE has decided?**

No, we do not, because this type of financing can put unnecessary restraints on expansion and unnecessary burdens on DOE's customers. It is our understanding, however, that this is not a financing method DOE has chosen, but one that has been mandated by OMB policy.

4. **Should a quasi-government corportion, similar to the Tennessee Valley Authority, be set up to run the enrichment business?**

We believe that an entity which is not constrained by governmental budgeting requirements and whose management is dedicated solely to providing reliable, low-cost enrichment services can contribute to the furtherance of the U.S. enrichment establishment. However, we are concerned that such an organization can only flourish if it enjoys the same relative freedom from regulation that DOE enjoys. If the regulatory and security obstacles can be overcome, we would favor such a corporation.

5. **Does EEI have a position on the privatization of the enrichment business?**

We favor privatization much as we do a quasi-government corporation with one additional caveat. In order for privatization to be successful and beneficial to the nuclear industry, easy entry by suppliers is a requirement so that competition can be fostered. Absent ease of entry, a private corporation would have to be regulated because of its monolopolistic position. Such a scenario may not be favorable as a quasi-government corporation.

Again, we wish to thank you for giving us the opportunity to appear at your February 28, 1984 Subcommittee hearing. If we can be of any further help, please let me know.

Sincerely,

George P. Rifakes
Vice President

cc: Mr. Loring E. Mills ✓